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INFLUENCE OF PISTON SPEED ON THE FRICTIONAL AND AIR RESISTANCES OF AN UNLOADED STEAM ENGINE AND ITS CONNECTED LINES OF SHAFTING IN A FACTORY OR MACHINE SHOP.

By Chief Engineer ISHERWOOD, U. S. Navy.

The writer having occasion, during some experiments conducted by him in the machine shop of the New York Navy Yard, to know the power consumed in overcoming the friction of its unloaded engine, and in overcoming the resistance of the unloaded numerous and long lines of shafting with their drums and belts driven by that engine, made, for the two cases, the determinations hereinafter stated of the mean indicated pressures on the steam piston required to give it different speeds varying from 15 to 70 double strokes per minute, both inclusive, and increasing by five double strokes at a time.

The engine experimented with had one horizontal, direct action, non-condensing cylinder, driving a shaft which carried a fly-wheel of 15 feet diameter and 9 inches face, and a drum of 7 feet diameter and 30 inches face. A leather belt, 30 inches wide and 60 feet long, connected this drum with the lines of the machine shop shafting. The following are the dimensions of the steam piston used:

Diameter of the piston, . . .	20 inches.
Diameter of the piston rod, . .	3½ inches.
Net area of the piston, exclusive of its rod, .	309·35 sq. in.
Stroke of the piston, . .	40 inches.

When the experiments were made with the main belt thrown off, the steam pressure on the piston being exerted in overcoming only the resistance of the engine, *per se*, that resistance was composed of the friction proper, and of the resistance of the air to the moving parts of the engine. The air resistance was due to displacement resistance and to surface resistance; the former being its resistance to the moving crosshead, connecting rod, arms of the fly-wheel, arms of the drum, etc.; and the latter being the resistance to the peripheral surfaces of the piston rod, connecting rod, shaft, fly-wheel, drum, etc.

When the experiments were made with the main belt in action upon the main drum, and driving the various lines of unloaded machine shop shafting together with thir drums and connecting belts, the resistance to the steam pressure on the piston in addition to the above was that due to the peripheral surfaces of these lines of shafting and their drums, to the surfaces of their connecting belts, and to the air displacement by the arms of the drums, etc.

By deducting the steam pressure on the piston required to give it the experimental speeds in the first case from the pressure required to give it the same speeds in the second case, the remainders will be the pressures required to drive the machine shop shafting, *per se*.

In such determinations the air resistance is generally included with the friction resistance proper, the whole being attributed to the latter. And, when the experiments are made with an unloaded engine alone, whose moving parts move slowly and are of great weight comparably with their surfaces, no error of practical value is thereby made. But, in the case of the lines of shafting, the air resistance becomes a very important constituent of the total resistance, for these lines being geared up to an extremely high speed, and having very extensive surfaces relatively to weight in their shafts, drums and belts, the resistance of the air increasing in the ratio of the square of the velocity of the shafting, while that of the friction remains constant, a velocity is practicable with which the air resistance may equal or exceed that of the friction. The current of air created by the face surfaces of fly-wheels and belts is so strongly sensible that the most careless observer cannot fail to be impressed with the power consumed in its production.

In order not to interfere with the regular work of the machine shop, and thus make the experiments without cost, advantage was taken of short favorable occasions, at different times, so that the experiments were not all made during the same day; portions of four days were consumed, but at no great intervals apart.

Two carefully tested indicators, with scales of 16 pounds per square inch per inch, were employed, one at each end of the cylinder, and the motion for them was taken direct from the engine crosshead by means of a long and stiff wooden lever centered upon the wall of the engine house. For each speed of piston, five indicator diagrams were taken from each end of the cylinder, and the mean of the pressures from the whole ten was taken as the true piston pressure for that speed.

During the experiments the journals of all the shafting were lubricated from oil cups of excellent construction, delivering the same quantity of oil per revolution of the shafts. The best sperm oil was used, and no change whatever was made in the manner of lubrication during all the experiments, which was exactly the same as when the engine was doing its regular work with 58 double strokes of the piston per minute.

Although the oil cups were arranged to *deliver* the same quantity of oil *to* the journals per revolution, it does not follow that the same quantity was *received by* them, the tendency being that after a rotary speed was attained at which the centrifugal force was large in proportion to the gravity of the oil, less and less of the latter went on the journals as their speed became higher and higher. If such was the case, the lubrication at the higher rates of speed was less than at the lower rates. As regards the engine journals, this could not have much effect, as their speed of revolution at the highest was within the limits of easy lubrication; but, as regards the journals of the lines of machine shop shafting, the case was very different, their rotary velocity at the highest being exceedingly great, as they were very much geared up. At very high rotary speeds, the writer, in some late experiments on the value of different lubricants, found much difficulty in getting any oil to flow from the cups upon the journals, the centrifugal action keeping back the liquid in the cup, although the feeding was satisfactory enough when the speed was sufficiently reduced to allow the gravity of the oil to overcome the centrifugal action imparted by the rotation of the journals. He was obliged in these cases to mechanically

force the oil out of the cup upon the journal by means of a loaded piston.

The experimental results will be found in the following tables, numbered 1, 2, 3 and 4.

TABLE No. 1, *showing the resistance of the engine, per se, at the experimental speeds of piston; the main belt being removed from the main drum and the engine worked unloaded.*

Indicated steam pressure on the piston, in pounds per square inch.	Number of double strokes made per minute by the steam piston. (Revolutions of engine shaft.)	Indicated steam pressure on the piston, in pounds per square inch.	Number of double strokes made per minute by the steam piston. (Revolutions of engine shaft.)
2·022	15	1·894	40
2·013	20	2·194	45
1·613	25	2·095	50
1·706	30	2·335	55
1·942	35	2·048	60

A simple inspection of the above Table, No. 1, shows that the piston pressure was the same for all the speeds of piston, the discrepancies being irregular, followiug no law, and very slight absolutely. Trifling inequalities in the friction of the indicator pistons easily account for the differences. The mean of the determinations for the ten different and widely varying speeds of piston is 1·9862 pounds per square inch of piston for the friction resistance of the engine, *per se*.

In the above Table, No. 2, the resistance appears to be constant from 15 to 25 double strokes of piston per minute; but from 25 double strokes upward there is a continual increase in the resistance, due to the causes hereinbefore stated. This increase, though marked, is irregular, owing doubtless to inequalities in the friction of the indicator piston, and to other causes impossible to eliminate or even discover in such experiments. It is highly probable that if the mean steam pressure had been obtained from a greater number of indicator diagrams for each speed of piston, more regularity would have been found.

TABLE NO. 2, *showing the combined resistance of the machine shop lines of shafting, and of the engine, per se, at different speeds of piston; the main belt being in action on the main drum, but with all the tools disconnected and no work being done.*

Indicated steam pressure on the piston, in pounds per square inch.	Number of double strokes made per minute by the steam piston. (Revolutions of engine shaft.)	Indicated steam pressure on the piston, in pounds per square inch.	Number of double strokes made per minute by the steam piston. (Revolutions of engine shaft.)
4·596	15	5·032	45
4·500	20	5·225	50
4·458	25	5·925	55
4·732	30	5·826	60
4·856	35	6·388	65
4·956	40	6·268	70

In the following Table, No. 3, are the results in Tables Nos. 1 and 2 corrected, that is to say, the friction resistance from Table No. 1, of the engine, *per se*, is taken at the constant 1·986 pounds per square inch of piston for all speeds of piston. The resistances in Table No. 2 are corrected by taking a straight base line and laying off on it as abscissæ, by scale, the number of double strokes made by the piston per minute; next, on right-angled ordinates to the base erected at the ends of these abscissæ, laying off, by scale, the experimental resistances in pounds per square inch of piston, and drawing a fair curve through the free ends of the ordinates, leaving as many ends on one side of the curve as on the other, and at the same distances; finally, measuring, by scale, from the base line to the curve on each ordinate for the corrected resistance at the corresponding speed of piston.

The experimental results under the actual experimental conditions are valuable in showing the practical effect of increasing the piston speed on the pressure required to overcome the resistance of the unloaded shafting. This is the point of interest for factories, machine shops, etc., and the experiments show that, owing to the causes hereinbefore stated, this pressure increases in some power of the piston speed, instead of being independent of it and therefore constant at all speeds,

as would be the case were the resistance purely frictional. Of course, each factory or machine shop constitutes a distinct problem and requires a separate solution. No general law can be given other than the qualitative one, that the pressure to overcome the resistance of unloaded shafting increases in some ratio of the piston speed. The experimental results also show that the resistance of the unloaded engine apart from the shafting, which resistance is almost one of pure friction, is constant and independent of the piston speed.

TABLE No. 3, *showing the corrected results of the experiments for ascertaining the separate resistances of the engine,* per se, *and of the machine shop lines of shafting,* per se, *at different speeds of piston.*

Number of double strokes made per minute by the steam piston.	Indicated steam pressure on the piston, in pounds per square inch, required to work the engine, *per se.*	Indicated steam pressure on the piston, in pounds per square inch, required to work both the engine and the unloaded shafting.	Indicated steam pressure on the piston, in pounds per square inch, required to work the lines of shafting, *per se.*
15	1·986	4·500	2·514
20	1·986	4·537	2·551
25	1·986	4·594	2·608
30	1·986	4·677	2·691
35	1·986	4·781	2·795
40	1·986	4·922	2·936
45	1·986	5·094	3·108
50	1·986	5·302	3·316
55	1·986	5·552	3·566
60	1·986	5·823	3·837
65	1·986	6·146	4·160
70	1·986	6·469	4·483

The resistance of an unloaded engine and its connected shafting is a *passive resistance* which can be overcome only by an expenditure of power; and as it must be overcome before the engine can move, the

pressure equilibrating it must, in the case of a loaded engine, be first deducted from the pressure on the piston shown by an indicator diagram, leaving the remainder for the net pressure applied to the crank pin. The overcoming of this *passive resistance* involves a very serious loss of useful effect, and as the portion of the indicated pressure applied to the crank pin is the only portion available for external work or commercially valuable, the same engine, kept at constant speed, will work more and more economically the more and more it is loaded; hence the principal advantage of using higher and higher mean indicated pressures on the piston; but this advantage grows less and less with each increment of indicated pressure, because the constant pressure required to equilibrate the friction of the unloaded engine and shafting becomes a less and less proportion of the indicated pressure the more the latter is increased. Practically, too, there is the loss due to more heat radiation and to greater steam leakage with each increase of the mean indicated pressure.

In order to appreciate the amount of power absorbed by the resistance of the unloaded engine and shafting of the machine shop of the New York Navy Yard, the following Table, No. 4, has been calculated for the experimental speeds of piston and for the corrected indicated steam pressures on it in Table No. 3. The horses-power thus expended are given separately for the engine, *per se*, and for the shafting, *per se*.

The power expended in overcoming friction reproduces its calorific equivalent in the rubbing surfaces. For a long time all held the belief, still held by many, that the heat produced by the friction of one solid upon another was due to abrasion of the material, or rupture of its cohesion; an idea plausibly sustained by the fact that the smoother and harder a surface was, and the better lubricated it was by an unctuous liquid, the less was its friction when moving under pressure, and the less also was the abrasion of the material. But this explanation is directly refuted by another fact, of which the world long remained in ignorance, namely, that the friction between the molecules of liquids develops heat in absolutely the same manner as the friction between the surfaces of solids, while it is evident that in the case of liquids there can be no abrasion of material. In fact, abrasion diminishes rather than increases the development of heat by the rubbing together of two surfaces.

TABLE No. 4, *showing the horses-power expended in overcoming the resistance of the engine,* per se, *and of the shafting,* per se, *at the different experimental speeds of piston and for the corrected steam pressures on it in Table No.* 3.

Number of double strokes made per minute by the steam piston.	Horses-power expended in overcoming the resistance of the engine, *per se.*	Horses-power expended in overcoming the resistance of the shafting, *per se.*	Aggregate horses-power expended in overcoming the resistances of the unloaded engine and shafting.
15	1·8617	2·3567	4·2184
20	2·4823	3·1885	5·6708
25	3·1029	4·0747	7·1776
30	3·7235	5·0452	8·7687
35	4·3440	6·1136	10·4576
40	4·9646	7·3394	12·3040
45	5·5852	8·7405	14·3257
50	6·2058	10·3617	16·5675
55	6·8263	12·2571	19·0834
60	7·4469	14·3876	21·8345
65	8·0675	16·8986	24·9661
70	8·6880	19·6116	28·2996

When a body undergoes friction, its molecules are mechanically thrown by the rubbing pressure into increased vibration, their resistance to which is what is known as the resistance of friction, and is directly proportional to the pressure producing the increased vibration. The heat developed by the friction being the result of, is also directly proportional to, the increased molecular vibrations, and, consequently, is directly proportional to the pressure producing them. There can be no other law of friction than this simple one of the direct proportionality of its resistance and of the heat generated by it, to the moving pressure which causes it, and all properly conducted and intelligently interpreted experiments sustain that fact. Hence the powers required to overcome the friction due to a given pressure, moving at

different velocities upon a given surface, are directly as the velocities. And the powers required to overcome the friction due to different pressures moving at the same velocity, upon the same surface, are directly as the pressures.

The effect of liquid unguents in diminishing the friction of solid rubbing substances between which they are interposed, is due to the fact that liquids oppose less resistance to increase of molecular vibration than solids. With perfect lubrication, the solids never come in contact, but they nevertheless undergo some friction. The increased molecular vibration is primarily given to the liquid alone, which then communicates a portion of it to the solids. The popular idea that if the solid rubbing surfaces be kept apart by a liquid unguent they will experience no friction is fallacious. Their friction in that case will, indeed, be a practical minimum, and very slight in comparison with what it would be with the surface in contact; but it will exist, and show its existence, in the fact of different solids having different coefficients of friction, with the same unguent, under pressures less than those necessary to produce contact, and with surfaces of the same degree of smoothness. The different friction coefficients of different solid substances, in the same condition as regards sufficient quantity of the same lubricant to prevent contact, pressure per square inch and smoothness of surface, are due to the difference of their resistances to increase of molecular vibration; in this respect, one substance being much better than another for practical use.

Measurement of Electromotive Force.—Pellat uses a method of opposition analogous to that of Poggendorff, combined with an electrometer, which he substitutes for the ordinary galvanometer, thus removing all fear of polarization of the measured element and of the interference of the resistance with the sensibility. Thus Daniell cells, with an internal resistance of 10,000,000 ohms, have been measured with the same electromotive force and with the same approximation as the largest cells. The standard employed was a Latimer-Clarke element; the compensatory circuit was a fine platinum wire; the intensity of the compensatory current was so regulated that each millimetre represented a difference of potential equivalent to a Latimer-Clarke millimetre. With this wire and a capillary electrometer Pellat secures an approximation of one two-thousandth.—*Soc. Franc. de Phys.* C.

NAVAL ARCHITECTURE.

No. 3.

By Chas. H. Haswell, C. E., M. E.
Member American Society of Civil Engineers.

To Compute Displacement Approximately.

Coefficient of Displacement of a vessel is ratio that volume of displacement bears to the parallelopipedon circumscribing immersed body $\frac{V}{L \times B \times D} = C$. *V representing volume of displacement in cube feet, L length at immersed water line, B extreme breadth,* and *D draught in depth of immersion, all in feet.*

Coefficient of Area of a Midship Section in Plane of a Water Line is ratio which their areas bear to that of circumscribing rectangle.

L representing length of water line, and D distance between water lines, both in feet.

Coefficients. By S. M. Pook, Constructor U. S. N.

Rule.—Multiply the length of the vessel at the load line by the breadth, and the product by the depth (from the load line to the under side of the garboard strake) in feet, and this product by coefficient for vessel as follows: divide by 35 for salt water, 36 for fresh water, and the quotient will give the displacement in tons.

Amidship sections range from ·7 to ·9 of their circumscribing square and the mean of the horizontal lines from ·55 to ·75 of their respective parallelograms. Hence the ranges for vessels of the least capacity to the greatest are $·7 \times ·55 = ·385$, and $·9 \times ·75 = ·675$.

Merchant ship, very full,	·6 to ·7
" " medium,	·58 to ·62
River steamer, stern wheel,	·6 to ·65
Ship of the line,	·5 to ·6
Naval steamer, first class,	·5 to ·6
" "	·52 to ·58
Merchant steamer, sharp,	·54 to ·58
Half clipper,	·52 to ·56

Brigs, barks, etc.,	·52 to ·56
River steamer, tug boat, medium,	·52 to ·56
Merchant steamer, medium,	·52 to ·54
Clipper,	·5 to ·54
Schooner, medium,	·48 to ·52
River steamer, tug boat, sharp,	·45 to ·5
" " medium,	·45 to ·5
" " sharp,	·42 to ·45
Schooner, sharp,	·46 to ·5
Yachts, sharp,	·4 to ·45
" very sharp,	·36 to ·4
River steamers, very sharp,	·36 to ·42

In the steam launch *Miranda*, when making 16·2 knots per hour, with a displacement of 58 tons, her coefficient was 3.

Coefficients. By C. Mackrow, M. I. N. A.

Description of Vessel.	Length.	Breadth.	Mean Draught.	Coefficient Displacement.	Coefficient Amidship sec.	Coefficient Water lines.
Iron Clads	225	45	15	·715	·932	·755
	325	59	24·75	·64	·81	·71
Mail Steamers	350	35	21	·687	·85	·84
	385	42	22	·659	·88	·8
	368·27	42·5	18·71	·516	·812	·635
Merchant, small	220	27	8	·702	·912	·742
	90	15	4	·637	·914	·704
Gunboats	125	23	8	·536	·87	·616
	160	31·3	12	·466	·745	·603
Troop Ships	350	49·12	23·5	·47	·674	·7
	340·5	46·13	15·75	·4	·68	·582
Swift Naval Steamers	337·3	50·28	22·75	·483	·787	·614
	270	42	19	·497	·792	·628
Fast Steamers, R. N.	300	40·27	14	·414	·711	·711

To Compute Centre of Gravity or Buoyancy Approximately.

$\frac{2}{5}$ to $\frac{9}{20}$ of *mean draught of hull*, using the larger coefficient for full-bodied vessels.

To Compute Depth of Centre of Gravity or Buoyancy Below Meta Centre.

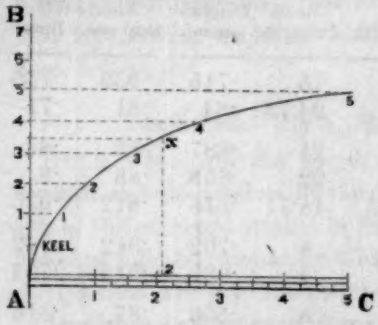
$\frac{S}{D \sin. M} = d$. *S representing statical stability, D displacement* in tons, *and* sin. *M sine of angle of heel.*

Illustration.—Elements of Fig. 2 (in preceding number, page 290) are statical stability at angle of 5·44° 90 tons, and displacement 204·33 tons.

Then $\frac{90}{204{\cdot}33 \times {\cdot}0999} = 4{\cdot}41$ feet.

To Delineate Curve of Displacement.

This curve is for purpose of ascertaining volume of water or tons weight, displaced by immersed hull of a vessel at any given or required draught; or weight required to depress a hull to any given or required draught. From results of computation for displacement of vessel, proceed as follows, Fig. 3:



On a vertical scale of feet and inches, as AB, set off depths of keel and water lines, draw ordinates thereto representing displacement of keel and at each water line in tons.

Through points 1, 2, 3, 4 and 5 delineate curve A 5, which will represent displacement at any given or required draught.

Draw a horizontal scale corresponding to weight due to displacement at load line, as AC, and subdivide it into tons and decimals thereof, and a vertical line let fall from any point, as x at a given draught will indicate weight of displacement at the depth or scale AC, and contrariwise a line raised from any point as z on AC will give draught at that weight.

Illustration.—Displacement of hull (illustration at pages 226–7) at load line = 71518 cube feet, which ÷ 35 for salt water = 204·3 tons, hence $A\,s$ represents tons and is to be subdivided accordingly.

Assume her launching draught to have been 6 feet, then a vertical let fall from 4 will indicate weight of hull in tons on AC.

CURVE OF WEIGHT.

To ascertain Number of Tons required to Depress a Vessel One Inch at any Draught of Water Parallel to a Water Line.

Rule.—Divide area of plane by 12, and again by 35 or 36, as may be required for salt or fresh water.

Example.—Area of load water line of a vessel is 1422 square feet. What is its capacity per inch?

$$1422 \div 12 = 108{\cdot}5, \text{ which} \div 35 = 3{\cdot}1 \textit{ tons.}$$

To Compute Common Centre of Gravity of a Vessel.

Rule.—Compute moments of weights of hull, spars, outfits, stores, etc., relatively to assigned vertical and horizontal planes, by multiplying weight of each part by its vertical and horizontal distance from these planes.

Add together these moments, according to their position forward or aft, or above or below these planes, and the difference between these sums will give position forward or aft, or above or below, according to which are the greatest.

Divide results thus asceratined by total weight of vessel, and product will give vertical and horizontal distances of centre of gravity from these planes.

It is customary to assume vertical plane at dead flat, and horizontal plane at load line.

Note.—In following illustration, in order to simplify computation in table, common centre of gravity of machinery, battery, etc., is taken instead of centres of individual parts, as engine, boiler, propeller, etc. etc.

To Compute Centre of Gravity of Bottom Plating of a Vessel.

Longitudinal.

Rule.—Measure half girths of plating at equidistant sections, as at two or more frames. Multiply these in accordance with Simpson's rule for areas and add products together.

Multiply each of these products, in their order, by the number representing the number of intervals of the section forward and abaft of

ILLUSTRATION.—*Vertical Plane at Dead Flat and Horizontal at Load Line.*

Elements of a Steam Frigate.	Weight.	Horizontal				Vertical			
		Distances.		Moments.		Distances.		Moments.	
		Forward.	Abaft.	Forward.	Abaft.	Above.	Below.	Above.	Below.
	Tons.	Feet.	Feet.			Feet.	Feet.		
Masts, spars, sails and rigging	24	27		648		31		744	
Anchors and cables	25	40		1000			6		150
Boats	3·25		48		156	16		52	
Battery and ammunition	131·5	62		8153		2		263	
Crew and effects	30	17		510		7		210	
Officers' and mess stores	7·25		40		290		8		58
Water and ship's stores	22	40		880			3		66
Engines, boilers, water and stores	470		29		13630		6·3		3011
Hull and cement in bottom	1075	1·6		1720			1		1075
Provisions and galley	30	1·2		360		5		150	
Coal	252	16		4032			4		1008
Total	2070			17303	14076			1419	5368

Moments before dead flat, 17,303 — moments abaft dead flat, 14,076 = 3227 ÷ weight, 2070 tons = distance of centre forward of dead flat, 1·56 feet

Moments above load line, 5368 — moments below load line, 1419 = 3949 ÷ weight, 2070 tons = distance of centre below load line, 1·91 feet.

dead flat. Divide difference of these moments by sum of products of half girths previously obtained. Multiply product by common distance between sections, and result will give distance of centre of gravity from dead flat in a horizontal plane.

ILLUSTRATION.—Assume half girths as in following table, and distance between sections 10 feet.

FORWARD.

Section.	Half Girths.	Multipliers.	Product.	Multipliers.	Moments.
No.	Feet.				
Dead flat...	25	1	25	–	–
A.....	23	4	92	1	92
B.....	21	2	42	2	84
C.....	19	4	76	3	228
D.....	17	2	34	4	136
E.....	15	1	15	5	75
					615
ABAFT.					
1.....	23	4	92	1	92
2.....	20	2	40	2	80
3.....	18	4	72	3	216
4.....	16	2	32	4	128
5.....	14	1	14	5	70
				534	586

Moments, forward, 615 — moments, abaft, 586 = 29 ÷ total product, 534 = ·054, which × 10 feet = ·54 feet forward of dead flat.

CENTRE OF LATERAL RESISTANCE.

Centre of Lateral Resistance is centre of resistance of water, and, as

its position is changed with the velocity of a vessel, it is variable. It is generally taken at centre of immersed vertical and longitudinal plane of a vessel when upon an even keel.

If a vessel is constructed with a drag to her keel, the centre will be moved proportionately abaft of the longitudinal centre.

Yacht *America* had a drag to her keel of 2 feet, and centre of lateral resistance of her hull was 8·08 feet abaft of centre of her length on load line.

Centre of Effort.

Centre of Effort is centre of pressure of wind upon sails of a vessel in a vertical and longtudinal plane. Its position varies with area and location of sails that may be spread, and it is usually taken and determined by the ordinary standing sails, such as can be carried with propriety in a moderately fresh breeze.

In computing this position, the sails are assumed to be braced directly fore and aft.

Note.—Centre of effort of sails, to produce greatest propelling effect, must accord with capacity of vessel at her load line, compared with fullness of her immersed body at its extremities. Thus a vessel with a full load line and sharp extremities below, will sustain a higher centre of effort than one of dissimilar capacity and construction.

To Compute Location of Centre of Effort.

Rule.—Multiply area of each sail in square feet by height of its centre of gravity above centre of lateral resistance in feet, divide sum of these products (moments) by total area of sails, and quotient will give height of centre in feet.

2. Multiply area of each sail in square feet, centre of which is forward of a vertical plane passing through centre of lateral resistance, by direct distance of its centre from that plane, and add products (moments) together.

3. Proceed in like manner for sails that are abaft of this plane, add their products together and centre of effort will be on that side which has greatest moment of sail.

EXAMPLE.—*Assume Elements of Yacht America as Rigged when in U. S. Service.*

Sail.	Area.	Height of cent. of gravity of sails.	Vertical moments	Distance of centre of gravity of sails. Forward	Distance of centre of gravity of sails. Abaft.	Moments Forward	Moments Abaft.
	Sq. feet.	Feet.					
Flying Jib..	65	28	18368	52		34112	
Jib	1087	26	28262	32		34784	
Foresail.....	1455	34	49470		3		4365
Mainsail.....	2185	35	76475		40		87400
	5383		172575			68896	91765

Vertical moments / Area of sails $\frac{172575}{5383} = 32{\cdot}06 =$ *height of centre above centre of lateral resistance.*

Moments $\frac{68896 \propto 91765}{5383} = 4{\cdot}25 =$ *distance of centre abaft centre of lateral resistance.*

RELATIVE POSITIONS OF CENTRE OF EFFORT AND OF LATERAL RESISTANCE.

For square rigged vessel $\frac{L\,(\cdot 75\ d'+d'')}{10\,(d'+d'')} = E.$

For fore and aft rigged vessel $\frac{L}{10\,(d'+d'')} = E$ and $\frac{4\ A}{5\ d} = E'.$ *L representing length of load line, d distance of centre of buoyancy of vessel below load line, d' distance of centre of lateral resistance abaft centre of load line, d'' distance of centre of buoyany before centre of load line, E distance of centre of effort before centre of lateral resistance, and E' distance of centre of effort above centre of lateral resistance.*

META CENTRE.

Meta centre of a vessel's hull is determined by location of centre of gravity or buoyancy of immersed bottom of hull, for it is that point in transverse section of hull, where a vertical line raised from its centre

of gravity or buoyancy intersects a line passing through centre of gravity of hull, as Fig. 3, page 290.

To Compute Height of Meta Centre.

By Moment of Inertia $\frac{I}{D} = M$. *I representing moment of inertia of area of water line or plane of flotation and D volume of displacement in cube feet.*

Note.—"Moment of inertia" of an area is sum of products of each element of that area by square of its distance from axis, about which moment of area is to be computed.

To ascertain Moment of Inertia approximately.

Rectangle $= CLB^3$ $C = \frac{1}{12}$: when $L = 4B$: $C = \frac{3}{50}$, $= 5\ B$: $C = \frac{11}{200}$, $= 6B$ $C = \frac{1}{20}$.

With very fine lines and great proportionate length $C = \frac{1}{25}$.

L and B measured at Load Line.

by moment of inertia.

Illustration.—Assume length of vessel 233 feet, breadth 43, draught 16 and displacement 2700 tons. Length $= 5{\cdot}65$ beams; hence C is taken at $\frac{21}{400}$. Volume of displacement $= 2700 \times 35 = 92{,}500$ cube feet.

Then $\frac{21 \times 233 \times 43^3}{400 \times 92500}$ 10·51. Exact height was 10·44 feet.

by ordinates.

Rule.—Divide a half longitudinal section of load water line by ordinates perpendicular to its length, of such a number that area between any two may be taken as a parallelogram. Multiply sum of cubes of ordinates by respective distances between them, and divide two-thirds of product by volume of immersion, in cube feet.

Illustration.—Take dimensions from Figs. 1 and 2, p. 225.

ORDINATES.

	Length.	Cube.
4	5·	125
3	7·7	456
2	9·5	857
1	3·9	970
Dead flat,	10·	1000
A	9·6	885
B	7·8	475
C	6·8	314
D	4·	64
		5146
		10
		51460
		2
		3)102920
	7151·8)	34306·6
		4·77 feet.

BY AREAS.

$$\frac{\frac{2}{3}(a^3+4b^3+2c^3+4d^3+e^3)\frac{l}{3}+F+A}{D}=M$$

a, b, c, d and e representing ordinates of 1*st or load water line, F area of irregular section between* 1*st frame taken and stem, and A area of like section between last frame and stern post, in square feet, D displacement, in cube feet, and l distance between frames or sections of water line, as may be taken, in feet.*

If there are more ordinates, their coefficients must be taken in like manner, as 1-4-2-4-2-4-1.

For operation of this method, see Simpson's rule for areas.

TO ASCERTAIN AREAS OF *F* AND *A*.

$$\frac{\frac{2}{3}\,a\,b\times b\,c^3}{4}=F \text{ and } \frac{\frac{2}{3}\,d\,e\times e\,g^3}{4}=A$$

WHAT IS THE MOST ECONOMICAL POINT OF CUT-OFF FOR STEAM ENGINES?

By Wm. D. Marks,

Whitney Professor of Dynamical Engineering, University of Pennsylvania, Phila.

Probably no question is more frequently asked, and has hitherto received more unsatisfactory replies from the experts in steam engineering, than What is the most economical point of cut-off for steam engines?

Some writers have recommended that the point of cut-off should be determined by dividing two by the square root of the steam pressure in pounds per square inch, although they have not stated their reasons when they stated their facts; others have passed this point over in silence, and still others have endeavored to determine the point of cut-off, giving the most economical results by many and costly experiments.

When we reflect upon the fact that nearly every man, woman and child in this country has laboring for it one horse-power in its steam engines, the immense saving derivable from a ready rule for the economical adjustment of the expansion of steam will appear in all its importance, and the writer therefore hopes that the following original investigation and enunciation of a simple rule will prove of much interest and profit to all using steam.

It will at once be perceived that the work done during one stroke of an engine is equal to the mean pressure multiplied by the volume of the cylinder swept through by the piston.

Let P = the mean pressure in pounds per square inch (absolute).

" P_b = the initial " " " "

" B = the back " " " "

" e = the fractional part of the stroke at which the steam is cut off by the valve motion.

" V = the volume of the steam cylinder.

" E = the economy.

Now it will further be acknowledged that the economy increases directly as the work done during one stroke and inversely as the steam used during one stroke. Therefore we have

$$E = \frac{PV}{eV} = \frac{P}{e} \tag{1}$$

We have further the well known formula for the mean effective pressure of steam used expansively, supposed to expand according to Mariotte's law—

$$P = e\,P_b\left[1 + l.\frac{1}{e}\right] - B \tag{2}$$

While this does not accurately represent the law of expansion of steam, it does it with close approximation, for all practical purposes. Substituting the value of P from equation (2) in equation (1), we have

$$E = P_b\left[1 + l.\,\frac{1}{e}\right] - \frac{B}{e} \tag{3}$$

Differentiating with respect to e, and seeking the maximum, we find it to be

$$e = \frac{B}{P_b} \tag{4}$$

That is, *the fractional part of the stroke giving the most economical point of cut-off for a steam engine equals the absolute back pressure per square inch divided by the absolute initial pressure of the steam per square inch.*

EXAMPLE.—In a condensing engine, let the gauge pressure = 45 pounds, and the absolute back pressure = 3 pounds.

$$e = \frac{3}{45+15} = \frac{1}{20} \text{ of the stroke.}$$

If the engine be supposed non-condensing, and the absolute back pressure = 15 pounds (1 atmosphere), we have

$$e = \frac{15}{60} = \frac{1}{4} \text{ of the stroke.}$$

If in equation (3) we substitute the value of $e = \frac{B}{P_b}$ we have

$$E = P_b\left[1 + l.\,\frac{P_b}{B}\right] - P_b = P_b\,l.\,\frac{P_b}{B} \tag{5}$$

which gives us a comparative estimate of the economy of the condensing and non-condensing engines having the same initial pressures.

Thus, for the non-condensing engine we have

$$E = 2{\cdot}3026\ P_b \log. \frac{P_b}{B}$$

or

$$E = 2{\cdot}3026 \times 60 \times 0{\cdot}60206 = 83{\cdot}17$$

and for the condensing engine we have

$$E = 2{\cdot}3026 \times 60 \times 1{\cdot}30103 = 179{\cdot}74$$

showing that, when both engines are worked to the best advantage, the condensing engine is more than twice as economical as the non-condensing engine. The writer proposes to add a more exact demonstration in the near future, but engineers will find the above method simple and exact enough for all ordinary practical purposes.

April 23d, 1880.

THE DECIMAL GAUGE.

By Robt. Briggs, C.E.

The Society of Telegraphic Engineers of London have had under consideration the subject of a gauge for wires to be used for telegraphic purposes. The conclusions of the committee (as reported in the *La Lumière Electrique* for Feb., 1880, which is the source from which the writer derived his knowledge of the action of the English society) correspond in some regards to the argument of the paper relating to a decimal gauge which appeared in the Journal of the Franklin Institute for December, 1877. Thus it is recognized at once that there exists a real necessity for a gauge for thickness of metal which shall not follow an arithmetical progression, but which shall give a constant proportionate ratio of decrement or increment, or, in other words, follow a geometric progression.

The ratios of progression proposed in the Journal in 1877 as expressed as relating to *the thickness* of the several numbers of the gauge were

For decrement $a\ 0{\cdot}9^N$ or $= \frac{1}{10}$ successive reductions.

For increment $a\ 1{\cdot}11111^N$ or $= \frac{1}{9}$ successive increases.*

* It will be noted that the increases of thickness for each number of the scale of $\frac{1}{9}$ are made by dividing the value below by 9, extending the division one decimal point in each instance, and that increases of weight for each number of the scale are made by two similar divisions.

These ratios gave, for the sections of squares or of rounds, or for the ratios of weights of equal lengths,

$a\,(0{\cdot}9)^{2N} = (0{\cdot}81)^{N}$ = the second reduction of $\frac{1}{10}$ successively,

$a(1{\cdot}11111)^{2N} = (1{\cdot}23456790)^{N}$ = the second reduction of $\frac{1}{9}$ successively,* or the values of successive numbers of the gauge.

The ratios of progression proposed by Mr. Clark, and which seem to have met the approval of the Committee of the Society of Telegraphic Engineers are made to relate primarily to the sections or weights, and secondarily to the thicknesses or diameters. Mr. Clark proposes that the relations to the sections or weights of equal lengths of the several numbers of the gauge shall be expressed

For decrement $a\ 0{\cdot}8^{N}$ or $= \frac{1}{5}$ successive reduction.

For increment $a\ 1{\cdot}25^{N}$ or $= \frac{1}{4}$ successive increase.

These ratios give, for the thicknesses or diameters,

For decrement $a\ 0{\cdot}89443^{N}$ or $= \frac{1}{9\cdot 47214}$ successive reduction.

For increment $a\ 1{\cdot}11801^{N}$ or $= \frac{1}{8\cdot 47386}$ successive increase.

If a metal gauge were adaptable solely to the uses of telegraphic engineers, the question of desirability for definite and aliquot relations of consecutive values might be referred to the derived sections or weights. But the necessities of commercial mechanisms apply generally to sheets as well as to wires, to diameters of wires as well as to their resulting weights, and it would seem that the consideration of the subject by any and each of the parties interested in the result should extend to the general utility. The writer also thinks that examination by telegraphic engineers will develop the fact that computation of weights and conductivities can be quite as readily effected by the two successive steps of decimal notation as by the single one which involves two processes in one case—a division and subtraction (or a multiplication by two figures) for decrement; or by multiplication by eight and movement of decimal point in the other, for increment. While it must be asserted that there are times when the ratios of diameters of wires is desirable knowledge to the telegraphic engineer, such ratios being entirely unattainable by Mr. Clark's system, except by comparisons of values of odd or even numbers of the gauge, which latter of course follow the ratios of weight or section, 0·8 or 1·25 reciprocally.

Whatever may be the scale of gauge adopted, the values as compared

with linear, superficial or solid units must be tabular. Although, by the proposed scale of decimal diminutions, each number referred to its following or preceding one has a comparatively simple ratio, yet when two remote numbers (some three or more grades apart) are to be compared in any relation of thickness, section or weight, simplicity of proportion will have been lost; and facility for use demands tables for reference. Such tables for many requirements, and for telegraphic engineers in particular, must be largely of reciprocal values. It is for reciprocal values that a system of progressive differences becomes superior to one of arithmetical differences. In the former system the ratios of reciprocal values are themselves reciprocal, while in the latter system the awkward figures which proceed from the attempt to express in decimal fractions the reciprocals of natural numbers, so generally prime to the decimal notation, bear so complicated a relation to each other that the relationship is unavailable in practice.

Thus, by the proposed system of the writer, the weights of equal lengths of squares or of rounds, for consecutive numbers of the gauge, are, as before quoted,

$$a \times 0{\cdot}9^{2N} \text{ for decrement of diameter or side of square,}$$

and are: $a \times 1{\cdot}11\ddot{1}^{N}$ for increment. " " "

And the reciprocals of these weights, or the lengths corresponding to any given weight, are expressed by

$$\frac{1}{a} \times 1{\cdot}11\ddot{1}^{N} \text{ for decrement of diameter or side of square.}$$

$$\frac{1}{a} \times 0{\cdot}9^{2N} \text{ for increment " " "}$$

In applying the system to electrical measurements, the values for conductivity and for resistance will be computed, the one after the first pair and the other after the second pair of these formulas.

To complete the applications of the proposed decimal gauge the writer has prepared the following tables, which would replace others or supply a deficiency of similar tables in the hand-books of the telegraphic engineers.

Table. Decimal Wire Gauge

Dimensions, Weights, Conductivities and Resistances at 0° Centigrade = 32° Fahrenheit, of Copper Wire annealed. Specific gravity taken at 8·891. Resistance derived from Reports of Committee on Electrical Standards, British Association for Advancement of Science.

"Resistance of pure copper wire, annealed, 1 metre long, 1 millimetre in diameter = 0·02057 ohm."

Number of gauge.	Values in Metric Units.						Values in English Units.				
	Diameter in centimetres.	Weight per metre of length in grammes.	Length in metres corresponding to one kilogramme or gramme.	Conductivity = length in metres per ohm.	Resistance of each metre in ohms.	Resistance of each nautical mile = $\frac{1}{60}$ degree of longitude in ohms.	Diameter in inches.	Weight per foot of length in pounds.	Length in feet corresponding to one pound.	Conductivity = length in feet per ohm.	Resistance of each foot in ohms.
0	1	2	3	4	5	6	7	8	9	10	11
—3	1·3717	1·313·91	0·76109	9147·7	0·0001093	0·20245	0·5401	0·88290	1·1326	30013·	0·00003332
—2	1·2346	1·064·27	0·93960	7409·6	0·0001349	0·24994	0·4861	0·71515	1·3242	24310·	0·00004114
—1	1·1111	0·862·06	1·1600	6001·8	0·0001666	0·30857	0·4375	0·57927	1·7263	19691·	0·00005079
0	1·	0·698·27	1·4321	4861·4	0·0002057	0·38096	0·3937	0·46921	2·1312	15950·	0·00006270
1	0·9	0·565·60	1·7680	3937·8	0·0002539	0·47031	0·3543	0·38006	2·6311	12920·	0·00007440
2	0·81	0·458·13	2·1828	3189·6	0·0003135	0·58063	0·3189	0·30785	3·2483	10465·	0·00009556
3	0·729	0·371·09	2·6948	2583·6	0·0003870	0·71683	0·2870	0·24936	4·0102	8476·4	0·0001180
4	0·6561	0·300·58	3·3269	2092·7	0·0004778	0·88497	0·2583	0·20198	4·9510	6865·9	0·0001456
5	0·5905	0·243·47	4·2822	1695·1	0·0005899	1·0926	0·2324	0·16360	6·1125	5561·4	0·0001798
6	0·5314	0·197·21	5·0709	1373·0	0·0007283	1·3489	0·2092	0·13252	7·5459	4504·7	0·0002220
7	0·4883	0·159·74	6·2601	1112·1	0·0008992	1.6652	0·1883	0·10734	9·3162	3648·8	0·0002741
8	0·4305	0·129·39	7·7285	900·84	0·001110	2·0559	0·1695	0·08695	11·501	2955·6	0·0003383
9	0·3874	0·104·81	9·5410	729·68	0·001371	2·5381	0·1525	0·07043	14·199	2394·0	0·0004177
10	0·3487	0·084·894	11·7790	591·04	0·001692	3·1335	0·1373	0·05705	17·528	1939·1	0·0005157
11	0·3138	68·764	0·01454	478·74	0·002089	3·8685	0·1236	0·04621	21·639	1570·7	0·0006367
12	0·2824	55·699	0·01795	387·78	0·002579	4·7759	0·1112	0·03743	26·715	1272·3	0·0007860
13	0·2542	45·116	0·02217	314·10	0·003184	5·8962	0·10008	0·03032	32·981	1030·5	0·0009704
14	0·2288	36·544	0·02736	254·42	0·003931	7·2792	0·09007	0·02456	40·716	834·74	0·001198
15	0·2059	79·601	0·03378	206·08	0·004853	8·9867	0·08106	0·01989	50·279	676·14	0·001476
16	0·1853	23·977	0·04170	166·93	0·005991	11·095	0·07296	0·01611	62·073	547·67	0·001826
17	0·1688	19·421	0·05149	135·21	0·007396	13·697	0·06566	0·01305	76·628	443·61	0·002254
18	0·1560	15·731	0·06357	109·52	0·009130	16·910	0·05909	0·01057	94·607	359·33	0·002783
19	0·1351	12·742	0·07848	88·712	0·01127	20·877	0·05318	0·008562	116·80	291·06	0·003441
20	0·1216	10·321	0·09689	71·857	0·01392	25·774	0·04787	0·006935	144·20	235·75	0·004242
21	0·1094	8·360	0·11962	58·204	0·01718	31·819	0·04307	0·005618	178·00	190·96	0·005237
22	0·09848	6·772	0·1477	47·145	0·02121	39·283	0·03877	0·004550	219·78	154·68	0·006465
23	0·08863	5·485	0·1823	38·188	0·02618	48·498	0·03489	0·003686	271·30	125·29	0·007981
24	0·07977	4·443	0·2251	30·932	0·03233	59·874	0·03140	0·002985	335·01	101·48	0·009854
25	0·07179	3·599	0·2779	25·055	0·03992	73·918	0·02864	0·002418	431·56	82·202	0·01219
26	0·06461	2·915	0·3431	20·294	0·04928	91·257	0·02544	0·001959	510·46	66·584	0·01502
27	0·05815	2·361	0·4235	16·438	0·06083	112·66	0·02289	0·001587	630·12	53·933	0·01854
28	0·05233	1·912	0·5230	13·315	0·07510	139·09	0·02060	0·001285	778·21	43·686	0·02289
29	0·04710	1·549	0·6456	10·795	0·09263	171·72	0·01854	0·001041	960·61	35·385	0·02826
30	0·04239	1·255	0·7987	8·736	0·11447	212·00	0·01669	0·0008432	1186·0	28·662	0·03489
31	0·03815	1·0164	0·9398	7·0762	0·14132		0·01502	0·0006830	1464·1	23·216	0·04318
32	0·03434	0·8233	1·2146	5·7317	0·17447		0·01351	0·0005532	1807·7	18·805	0·05318
33	0.03039	0·6669	1·4995	4·6427	0·21539		0·01217	0·0004481	2231·6	15·232	0·06565
34	0·02781	0·5402	1·8512	3·7606	0·26591		0·01095	0·0003630	2754·8	12·338	0·08105
35	0·02503	0·4375	2·2857	3·0461	0·32828		0·009856	0·0002940	3401·4	9·9939	0·10006
36	0·02253	0·3544	2·8217	2·4673	0·40530		0·008870	0·0002381	4199·9	8·0950	0·12353
37	0·02028	0·2871	3·4831	1·9985	0·50038		0·007983	0·0001929	5184·0	6·5570	0·15251
38	0·01825	0·2325	4·3011	1·6188	0·61773		0·007185	0·0001562	6402·0	5·3112	0·18828
39	0·01642	0·1883	5·3107	1·3112	0·76265		0·006466	0·0001266	7898·9	4·3020	0·23245
40	0·01478	0·1526	6·5531	1·0621	0·94151		0·005819	0·0001025	9852·2	3·4847	0·28697

Table for Calculating Resistance or Conductivity of Pure Metal as affected by Differences of Temperature.

Data from Lecture of Fleeming Jenkin, Esq., Reports of British Association for the Advancement of Science.

"$R = r\,(1 + 0{\cdot}003824\,r + 0{\cdot}00000126\,r^2)$" "approximate or mean formula."

[Temperatures in degrees Centigrade.]

Temp. C.	Resistance.	Conductivity.	Temp. C	Resistance.	Conductivity.
0°	1·00000	1·00000	100°	1·395	0·71685
1	1·00383	0·99619	21	1·08086	0·92519
2	1·00765	0·99240	22	1·08474	0·92188
3	1·01148	0·98865	23	1·08861	0·91860
4	1·01532	0·98492	24	1·09250	0·91533
5	1·01915	0·98121	25	1·09639	0·91208
6	1·02299	0·97751	26	1·10028	0·90885
7	1·02683	0·97386	27	1·10417	0·90565
8	1·03067	0·97023	28	1·10806	0·90248
9	1·03452	0·96663	29	1·11196	0·89932
10	1·03837	0·96305	30	1·11585	0·89618
11	1·04222	0·95949	31	1·11976	0·89305
12	1·04607	0·95596	32	1·12366	0·88995
13	1·04993	0·95245	33	1·12756	0·88686
14	1·05379	0·94896	34	1·13147	0·88380
15	1·05765	0·94550	35	1·13539	0·88075
16	1·06151	0·94206	36	1·13930	0·87773
17	1·06537	0·93864	37	1·14321	0·87473
18	1·06924	0·93524	38	1·14713	0·87174
19	1·07311	0·93187	39	1·15105	0·86877
20	1·07698	0·92852	40	1·15498	0·86580

Chlorhydrate of Phosphuretted Hydrogen.—The analogies between phosphuretted hydrogen and ammonia, which are indicated by the formation of compounds with bromhydric and iodhydric acid, are well known. Ogier has also obtained a chlorhydrate of phosphuretted hydrogen by chilling or compressing a mixture of the two gases $PH_3 + HCl$ in equal volumes. The experiment may be easily performed in the Cailletet apparatus; under a pressure of about twenty atmospheres and a temperature of 14° (57·2° F.) the upper part of the tube is covered with small brilliant crystals.—*Bull. Soc. Chim.* C.

REVIEW OF THE REPORT ON THE IRWIN INJECTOR.

By Wilfred Lewis, M. E.

The report of the Committee on Science and the Arts, published in the February number of the Journal, and containing a series of experiments upon the injector and ejector of J. H. Irwin is valuable rather for the experiments themselves than for the deductions and views gathered from them. The generalization of observed facts, and their subjection to known laws and principles, is, however, the most important part of experimental research. It is by this means that new relations are discovered, and better knowledge is gained, without which improvement must be more or less accidental and uncertain.

A crude general theory for the action of injectors is well known to all who are familiar with the instrument; but something more definite is needed before it is possible to determine theoretically the performance of an injector under various conditions from the dimensions of its parts, or what is perhaps of greater importance, to determine the proper proportions for certain desired results.

The present subject is surrounded by so many difficulties and apparent contradictions that any attempt to develop a satisfactory theory upon fundamental principles can hardly be expected to be at once successful. It is therefore only in the hope that a better understanding may ultimately be reached that the following theories and criticisms are offered:

In the first place, it has been claimed for the Irwin Injector that it is constructed on a certain fixed rule of proportion of parts, the discovery of which proportion is the important feature of the invention. The value of the discovery is further claimed to be demonstrated by experiments showing that an injector constructed on this new formula has a wonderful power of augmentation.

The determination of this property of the injector seems to have been the primary object of the experiments, while another more important one, namely, that of "range," has been left in the background.

With this supposed object in view the results are perhaps as good as occasion may ever require, but, with few exceptions, the demand upon

an injector is not to overcome pressures greatly in excess of the steam pressure, but to be able to supply water to a boiler at the rate of evaporation, whether this be slow or rapid, and this ability to vary the quantity of delivered water is what is understood by the term "range."

It is well known among manufacturers of these instruments that one desideratum can only be perfected at the sacrifice of others, and that injectors which give good results for range have less power of augmentation, and *vice versa*.

It is therefore difficult to understand how any rules for the proportions of parts can be made general; and how an injector, which gives such good results for augmentation as that of Mr. Irwin, could have been made, as we are led to suppose, according to a law governing its economic action.

The power of augmentation depends upon the velocity and density of the fluid jet in its passage from the combining to the delivery tube, the velocity, in turn, depends upon the proportion of water to steam, and the density, to some extent, upon the duration of their contact before leaving the combining tube.

The less the proportion of water thrown, the higher the velocity and temperature of the mixed water and steam, the slower the rate of condensation and the shorter the time of contact, from which it can be inferred that the proportions favorable to augmentation would be a larger steam nozzle with a longer combining tube than could reasonably be used on an injector designed for economic action. When the injector is used as a boiler feeder its action is economic under all circumstances, and its duty, as stated in the report, is comparatively unimportant, but when used as an ordinary pump the increased temperature of the feed water may no longer be regarded as a useful form of energy, and the economy must be measured by the mechanical effect produced.

For such a purpose, then, the greater the amount of water thrown, and consequently the slower the velocity of the fluid jet within the working limit, the greater the economy as far as mechanical effect and the slight losses by radiation are concerned. The water pressure is in most cases equal to that of the steam producing the jet, and the problem long sought has been to increase the range, that is, to vary as much as possible the quantity of water thrown, in order that a boiler may always be suplied at the rate of evaporation.

The greatest range can be obtained when the greatest possible amount of water is thrown with the steam jet full open. As the steam and water are shut off, the velocity of the mixture must increase, while its density must necessarily decrease, from the fact that a smaller quantity of fluid has to pass through the same sized openings. In order that the fluid of lighter density may overcome a constant resistance, it is evident that its velocity must be increased, and this can only be done by the reduction of the ratio of water to steam.

To determine theoretically the possible range for an injector, it is necessary to know the velocity of efflux of steam and the precise nature of the causes which operate to break the jet.

The most obvious of these causes are want of velocity and density, pressure at the overflow and friction. When the effects of friction and pressure at the overflow can be accurately determined, the injector itself should furnish the best data for computing the velocity of steam, upon which authorities so widely differ. The effects of friction become apparent in the augmentation and range of similar injectors which differ principally in size, and might be determined from a comparison of the results.

The quantity of water delivered depends more upon the conditions at the overflow than upon the pressure overcome, and experiments have shown that there is often no difference between the quantity delivered into the atmosphere and that delivered into the boiler. The reason is clearly because it is not possible to transmit pressure through an open jet except by the pressure surrounding it, and so long as the conditions at the overflow remain constant, the velocity and density of the jet on leaving the combining tube are independent of the pressure afterwards overcome by it. When there is pressure at the overflow the force of the jet will be affected by the density of the fluid producing that pressure as well as by the pressure itself, and when water accumulates, the power expended in its agitation must be sufficient to explain in part the higher degrees of augmentation which can be obtained with waste at the overflow. In the absence of more accurate knowledge, approximate data for computing the velocity of steam might be obtained from an experiment of the following kind:

Let the injector be in full operation, with overflow open, and let the resistances to the delivered water be increased until waste commences, then the pressure equivalent to the combined effects of pressure and friction has become equal to that due to the average velocity and

density of the jet. The quantity of water delivered and the total pressure overcome are sufficient data for determining the velocity and density of the jet. The velocity of the jet multiplied by the ratio, plus one of water to steam, will give the velocity of steam. In this experiment, the larger the injector the smaller the effect of friction, and the more reliable will be the result.

It is claimed in the report that the free entrance of atmospheric air at and through the overflow gives a clear gain to the extent of one atmosphere in the same direction.

In this case the injector was running without waste at the overflow, and no water pressure could accumulate by its stoppage; consequently there appears to be no reason why the phenomenon could not have been attributed to the suction of air by the jet into the delivery tube, nor why an increase of pressure might not have been effected in the same way by increasing the water supply.

The injector evidently had not enough water for the steam used, and it took in air whenever the opportunity offered.

The fact, as reported, that the temperature of the delivered water fell from 136° with overflow closed to 127° with it open, some steam being shut off to keep the water pressure constant, is not conclusive proof that "the steam so shut off was undoubtedly saved," as we are led to infer by the presence of the atmospheric air.

It is highly probable that the temperature of the delivered water could have been reduced in the same way with the overflow closed, and it is to be regretted that after the instrument had been adjusted to the water pressure of 83 pounds, with overflow open, that the temperature and pressure of the delivered water was not again taken with the overflow closed. In fact, the fallacy of the above assertion can be shown by Experiment *A* itself; for, as we see, the temperature of the delivered water was 138° with overflow open and only 136° with overflow closed; hence, more water must have been passing through the injector when the overflow was closed than when it was open; and yet, as we see further, 10 pounds more resistance was offered by the globe valve in the delivery pipe to the passage of the smaller quantity of water. The conculsion is inevitable that something besides water was taken in by the jet, and this must have been the air admitted through the overflow.

With regard to the experiments themselves, and the calculated columns in the tables, but one objection, of minor importance, can be

made, while great praise should be accorded for the manifest care and labor on the part of the committee in their preparation.

The objection made is to the method of computing the percentage of error given in column 20. By reference to the report the following expression will be found

$$(1 + X)\,D - X\,F = R + E,$$ in which

R = the total heat of 1 pound of steam for the observed pressure taken from Regnault's tables.

D = the specific heat of the delivered water for the observed temperature.

X = the weight of feed-water delivered per pound of steam.

F = the specific heat of the feed-water for its observed temperature.

E = error of the experiment.

The objection is made on the ground that the total heat of steam as given in Regnault's tables is measured from an arbitrary zero, 32°F., which, while it does not affect the value of E, has, nevertheless, considerable influence upon the value of the expression $(1 + X)\,D$, which forms the denominator of the fraction in computing the percentage.

It would seem logically more correct to determine the percentage of error from a comparison of the calculated and actual quantities of steam used, and this would then give a definite amount independent of any assumed zero of temperature. For instance, in the first experiment 7 per cent. is given as the percentage of error, and we also have from the table:

Weight of feed-water lifted, . .	= 471·5 lbs.
Temperature of feed-water, . .	= 62·5°
" " delivered water, .	= 104·°
Increased temperature of feed-water, . .	= 41·5°
Thermal units abstracted from steam, 41·5 × 471·5,	= 19567·
Thermal units in 1 pound of steam above 104° from Regnault, . . .	= 1086·

The theoretical weight of steam condensed would therefore be $\frac{19567}{1086}$ or about 18 pounds.

The observed weight of condensed steam was 20·5 pounds, a difference of 2·5 pounds.

This difference may be due to priming, radiation, or to errors in observation, but the error of the experiment as deduced from it will be $\frac{2 \cdot 5}{20 \cdot 5}$, or about 12 per cent.

It is hoped, in closing this review, that the suggestions and theories advanced may lead to a more thorough and scientific study of the subject than can be derived from experiments designed to show the performance rather than to determine precisely the causes which limit and control the action of injectors.

EYE-MEMORY.

A Lecture delivered before the Franklin Institute March 29th, 1880,

By CHARLES G. LELAND.

(Continued from page 336.)

The writers on the Kindergarten, and on object-teaching in connection with elementary drawing, have hit on a great truth in their endeavor to teach children to form *definite* impressions. But I doubt if any of them, or any one living, knows how indefinite all our memories of objects are, compared to what they might be. Object-teaching causes children to learn the appearance, names and qualities of things. "And many persons," says Mrs. Horace Mann, "object to it because it is playing with things, and the opposite of study." The cultivation of eye-memory must, however, be admitted by the greatest enemy to all new ideas in education, to combine all the discipline of intense study with all that is useful in object-teaching. It is the very opposite to anything like loose thinking or vagueness. It calls for the closest observation and the greatest exercise of the memory conceivable. Therefore it is good discipline for the mind, therefore it should be a legitimate branch of education. But be it observed that this practice of the visual memory, while requiring intense application and much practice, is not disagreeable in the sense in which much study is disagreeable. In fact it cannot be pursued with profit an instant after it becomes wearying. As soon as you tire of it, then, in the words of Westwood, "the visions flee and the dreams depart." The memory will only work of her own accord at this; she will only remain as a willing guest. Force her, and she flies.

On the other hand, *success* in the practice of visual memory is so encouraging that after we once realize our progress the most strenuous effort becomes in fact a voluntary pleasure. I conceive that for its cultivation classes should be formed, at which maps, pictures or any

objects being shown for a minute, or for several minutes, those assembled shall endeavor to impress what is set forth on the memory. Now the difficulty at the very outset will be that many of those present, instead of literally getting the object *by eye*, and making the exertion necessary in the beginning will—perhaps unconsciously—make up their minds at a glance as to what the object is, and then in their description or depicting make a clever enough superficial account. These are the ones who, in drawing from a model, look at it a thousand times, carelessly, and yet lose half of what they had gathered in every glance, and make it up by drawing as they think it ought to be—not as they have actually *seen* it. Strictly honest work, and a desire to improve keenness of observation and accuracy of memory, will soon remedy this defect.

I attach great value to bold outline drawings, such as are used in primary classes, as introductory subjects for such study. These, by their simplicity and the striking contrast between white and black which they present, make an impression which is easily retained by an effort of the will. If this impression be recalled frequently during a week, and occasionally revived by study of the original, it will become permanent. Two things are to be observed in connection with this *first* study. Firstly, it is of the greatest importance that it be accurately and correctly conceived, since every error of method which you introduce into it will probably be repeated in the second trial and grow in strength with every successive effort. It is the first notes of the birdling which are almost unchangeable. Secondly, that the more thoroughly it is effected the easier will the next experiment be. It is not advisable that there should be any straining to learn the object in a hurry. Your mind may possibly be involuntarily distracted by some other cause. Your physique may be slightly disorganized. You may be constitutionally of the disposition which requires many gentle and gradual repetitions to impress anything on your memory. Hasten slowly.

Practice in anything makes perfect. From outline drawings you may proceed to objects, from simple objects to statues and the human figure. I have spoken of people who can recall a piece of music, who can literally see in the mind's eye every note, and play from it. I have also mentioned the clergyman who learned his sermons by eye. I think that this might be effected by beginning with a single line, let us say a text or a proverb, very legibly written in bold, thick let-

ters, at least an inch in length, and, in learning them perfectly by eye, care being taken that the imagination shall have no part in re-writing them on the memory. The number of lines may be increased and their size diminished as the power of acquisition is developed.

We all know that, in some way, this power of recalling objects vividly is latent in us. We read familiar books in our dreams, we see the departed, we recall past scenes in reveries, we sometimes imagine faces and remember them after waking. In fevers and in similar states of nervous excitement we think that we see phantoms mingling with real objects. What we thus create involuntarily, in an unhealthy condition, we can also produce healthily, and subject to the laws of reason, by voluntary action. In these dreams, scenes are recalled by association. I have already said that the awaking in our memory of every detail of a scene connected with some startling incident is a fertile theme with novelists. I shall never forget the wonderful, the magnificent sunset which followed the burial of Washington Irving. The western sky, like a vast sea of golden fire, in which were islands of a deeper crimson glow, as though Heaven had thrown its glorious gates ajar to welcome the ascending soul, will always be impressed on my memory. I have doubtless in my time seen sunsets as beautiful in the Far West on the prairies; on the plains of Russia, or in Egypt; but I cannot remember any of them as I do that one on the Hudson.

It may, perhaps, be thought that as all of this is so generally the result of involuntary action, there is no connection to be established between it and the will. Those who would understand this problem, so far as it has in all probability been solved, may read what Carpenter has said in his *Mental Physiology* of primarily and secondarily automatic motion. What I assert is that the will can stimulate involuntary or automatic motion. Did it never happen to you that you cannot recall a certain tune until you by an exertion remembered the *place* where you heard it, or the person who played it? Sometimes, in order to remember a certain remark, you must first recall the time of year when you heard it, then the city in which you were, then the house in which you dined, and finally the person who was seated by you who made the remark. All of these preliminary steps are recalled by deliberate, voluntary action. It is not necessary to enter into a metaphysical analysis of theories of free will and causation. You will probably admit that we can revive, in a more or less perfect form,

when we choose, that which we remember, and that the vividness of these memories can be increased by practice.

The practice of eye-memory stores the mind with beautiful images, and increases our artistic sense. It may developed so as to place at our disposal galleries of pictures and statues, scenes in the opera, landscapes or picturesque bits, the forms and faces of friends, or, in fact, whatever we have seen. It may be denied by many that such a power exists in us to such a degree, but I venture to assert that, among all who are present, there is probably not one who has done his best to develop it. For there is no mental faculty, involving so much which is useful or curious, which has received so little attention.

I will now enter upon an abstruse and yet very practical phase of eye-memory, which is also closely analyzed by Carpenter and Clarke. Robert Houdin, in his *Autobiography*, carefully explains that whilst performing his Second Sight he always practiced a *double-consciousness*. That is to say, while performing his trick, he, at the same time, kept in mind the objects which he had *memorized*. In fact, he lays much greater stress upon this double, or simultaneous, action of the mind, than upon the extraordinary feat of getting thousands of objects by heart. Every juggler will understand this. Every juggler knows what "working" means. It means, while substituting an object, or effecting "hanky-panky" by *manipulation* (which requires the shrewdest mental action), to divert the attention of the audience at the same time in another direction. Should he even tell you that at exactly nine o'clock he would pick up a rabbit, with his right hand, from behind a screen, and put it into a hat before the audience you would not see him do it. Because at that very instant he would raise his left hand and snap his fingers in the air, or point to something. If there were a thousand persons present, every eye would be caught and drawn away by the left hand, and during that instant the rabbit would be taken out and put in the hat and nobody present would see it. To do this, the juggler must exert a double action of the mind. The simplest form of this is seen in the child's trick of rubbing one hand up and down on the chest, while you pat your head with the other. Robert Houdin illustrates this by telling us that while obliged to study law in his youth, he, while reading, used to keep tossing four balls in the air.

Now, there is certainly the same double action of the mind while drawing. It requires thought to observe the model, or to form the

ideal in the mind, and it also requires thought to perform the action of drawing. You cannot get over this by saying that the drawing becomes merely mechanical. While I have been writing this lecture I have thought of the formation of every letter while I wrote. There are people who are said to write mechanically, but I cannot. Should I do so my writing would be illegible, even to myself. You would say, perhaps, that to do two things at once must detract something from both. I find, invariably, that the more I think about something else, the more carefully I write. Ladies say that they can sew best while talking. I have heard of an actress who was never so thrilling in her tones, never so heartrending, as while embracing her rival; she was at the same time pinching her. This was also a double action of mind. There used to be something of the same kind when I was at college, among the young gentlemen who read novels in chapel during sermon-time. Yet, on reflection, I doubt if in this instance the mental action was exactly balanced.

I have met in my life with two instances of sculptors, both Frenchmen, who required but a single glance at any man to be able to model a perfect likeness of him. One of these artists, M. Garbielli, once took an admirable and very expressive portrait of James Gordon Bennett, whom he had seen only once, as the original went by rapidly in a carriage. A very curious instance of the length of time during which a picture may remain accurately impressed on the memory, is shown in a feat performed by Mr. John Sartain, well known as one of the ablest advancers of art in Philadelphia. Thirty-five years ago, when the old Academy of Fine Arts, in Chesnut street, was burned, there perished in the fire a very valuable picture by Murillo, entitled The Roman Daughter. Very recently Mr. Sartain has drawn it from memory. And Dr. Abercrombie tells us that in the church of St. Peter, in Cologne, the altar-piece is a fine picture by Rubens. This was carried away by the French in 1805, but a local painter made from memory a copy which seems to be absolutely perfect. The original has been restored, and the copy is preserved along with it, and even when rigidly compared it is impossible to distinguish one from the other.

There is in this city a gentleman named John Ryder, a Jessup student at the Academy of Natural Sciences. I am told that he has the power of instantaneous observation, and of subsequently copying, to a degree which far transcends anything I have as yet heard of. Thus,

having seen but for an instant any of the rapidly moving animalcules in any medium, through a microscope, he will produce a perfect likeness of it, admirably colored and shaded. I am under obligation to Mr. D. S. Holman, the Actuary of the Franklin Institute, for this curious and valuable illustration of the advantages of eye-memory. And since recording this instance I learn that Dr. Joseph Leidy, of Philadelphia, possesses the same power to as great a degree.

One of the first physicians in Baltimore has informed me that there is in that city, a patient of his, a gentleman who possesses eye-memory to a degree far transcending anything of the kind on record. He can recall, it is said, visually, entire books which he has read years ago, and remembers anything he reads whenever he exerts the determination to do so at the time of perusal.

I know personally a lady, Mrs. Eleanor Meredith, a teacher in Philadelphia, who at one time, in consequence of illness, lost her mental memory. In order to restore it, she practiced getting poetry by heart, beginning with a poem of Longfellow's of about 300 lines. She could not learn it as she wished, but the result of strenuous effort was its visual acquisition, every line and mark becoming visible at will. After a time the lady's mental memory returned. This case is curious, as indicating an absolute difference between mental and visual memory. I have also met with another lady teacher in the same city, who was induced to turn her attention to art by finding herself possessed, to a remarkable extent, of eye-memory. A certain landscape, which she could recall at will, delighted her so much that she determined to draw it. It was her first effort, and after many trials she succeeded in producing a tolerably good picture. There is a waiter in New York who is much employed at balls to snperintend the *guarda roba*. He can identify the owners of five hundred hats in one evening. He does this by associating the face of the wearer with his hat and recalling it by eye-memory. "I put the face under the hat and then I know whose hat it is," he says. I know a hotel clerk who remembers with an accuracy which is literally marvelous every trunk which comes to the hotel. There are in America many hotel keepers who, like the late Mr. Willard, rival Mithridates in their memory of faces.

I learn that in the Art School of Boston the practice of drawing with the model removed, as at St. Petersburg, is followed with happy results. I think that, after what I have said on this subject, that no one who will carefully examine it can doubt that the application of

eye-memory to free-hand drawing can have anything but happy results. It must be remembered, however, that it requires patience. The faculty is, so to speak, not only dulled and blunted in us by never having been used, but is changed by having been vigorously developed in other directions. Therefore I trust those who experiment on it will persevere and not be discouraged because the experiments of a few days do not yield marvelous results.

There is a faculty so closely allied to eye-memory as to be effectively identical with it. This is *quick comprehensiveness*, or rapidity of sight with intelligence. It is the art of seeing and understanding objects completely, even when in motion, in less time than the great majority of people take in so doing. Educationally its practice would form the next step beyond that of eye-memory. It has also to a degree been applied in object teaching. Eye-memory stores the memory with phenomena; quick comprehensiveness gives rapidity of perception and of thought. For merely mechanical rapidity of observation, induced by mechanical methods, will awaken mental activity at last, even in very dull minds. I regret to say that almost the only people who appear to thoroughly cultivate this invaluable accomplishment are thieves and detectives. It is usual, in training young sneak thieves, for the preceptor, holding a variety of small objects in one hand, to open and close the hand rapidly, and to require his pupils to ascertain at a glance what he holds. They rapidly attain an amazing cleverness and quickness in such perception. A boy thus trained is sent out, ostensibly to beg. He obtains admission to a kitchen; he may get a glimpse of a drawing-room, and with that glimpse he takes in everything, remembers everything, and returning reports what he has seen. There are other people, *not* thieves, who develop the same faculty in observing what is none of their business. They pry and "snoop" about, to use an admirable New York word, which exactly expresses such observation, and go home with what they have got to gossip it. This power of *unusual* quickness of perception, seldom acquired by honorable practices, is generally transmitted to children. It becomes hereditary, and may then be honorably applied. I have had much experience of gypsies, and have observed among them a great development of this faculty. Those petty swindlers who go into shops and practice what is called ringing the changes, or cheating in making change, also develop remarkable quickness of perception. Italians are supposed to acquire it by playing *morra*. Civilization and

ordinary education rather repress this faculty than develop it. It is to be regretted that an accomplishment which is capable of contributing so much to our general intelligence, and to the exercise of all our intellectual faculties, should really be deliberately cultivated in its purity chiefly by the vicious and the mean.

On the other hand, the detectives who hunt these foxes are obliged to become almost as clever. Many years ago Chief Marshal Stevens, of New York, told me that he wished to ascertain the character of a man who occupied a certain room which was always kept carefully closed against all intruders. One day he knocked, and the door was opened a few inches for an instant. During that instant his keen eye took in all the contents of the room. He saw that it was hung all round with suits of clothes of a very varied description; he knew at once that they were used for disguise, and observed that some of these disguises were the same as those which had been worn by the man whom he "wanted." One of the most intelligent men whom I have ever known is Robert Walker, Inspector of Police in London. He says that most people, as they walk along a street, look habitually chiefly to the right hand, and that newly enlisted policemen are trained to overcome this habit and look to both sides, so as to become generally observant.

I have spoken of the fact that children receive and retain visual impressions better than grown people. I certainly should not omit to state that Mr. Francis Galton has remarked that women are endowed with this faculty to a much greater degree than men. This great observer has remarked, in *Nature*, that women are not only better gifted than men with what he calls "mental imagery," but that they surpass us in the readiness with which they appreciate the scope and sense of inquiry into it. He says: "I have been astonished to find how superior women usually are to men in the vividness of their mental imagery, and in their powers of introspection. Though I have admirable returns from many men, I have frequently found others, even of the highest general ability, quite unable for some time to take in the meaning of such questions as these: 'Think of some definite object, say your breakfast table, as you sat down to it this morning, and consider carefully the picture that rises before your mind's eye. Is the image dim or fairly clear? Is its brightness comparable to that of the actual scene? Are the objects sharply defined? Are the colors quite distinct and natural?' etc. On the other hand, I find the attention of women, especially women of

ability, to be instantly aroused by these inquiries. They eagerly and carefully address themselves to consider their modes of thought, they put pertinent questions, they suggest tests, they express themselves in well-weighed language and with happy turns of expression, and they are evidently masters of the art of introspection. I do not find any particular tendency to exaggeration in this matter either among women or men; the only difference I have observed between them is that the former usually show an unexpected amount of intelligence, while many of the latter are as unexpectedly obtuse. The mental difference between the two sexes seems wider in the vividness of their mental imagery and the power of introspecting it than in respect to any other combination of mental faculties of which I can think."

After such a compliment from such a man it would be indeed ungrateful should the ladies who may meet with these remarks neglect the subject.

As summary and conclusion, I would remark that the development of eye-memory, to a greater or less extent, is within the power of almost everybody. No accomplishment affords such lasting pleasure, and it costs nothing. It can be exercised at any odd time without any preparation. In acquiring it stick to one subject until you can recall every detail of its shape and color. Remember that with young people the development of *quick observation* in a merely mechanical manner leads invariably to mental and intellectual quickness of perception. This wonderful fact, except as far as it has been developed by object teachers, is as yet entirely ignored in education, except by thieves and gypsies. A quick eye develops a quick mind, and a quick eye may be developed by training. And I trust that, from what I have said, you will agree with me that eye-memory, though it is as yet little studied, is destined to exert, at no distant day, a great influence on art and on education.*

Malleable Bronze.—P. Dronier, in Paris, makes alloys of copper and tin malleable by adding from ½ per cent. to 2 per cent. quicksilver. —*Dingler's Journal.* C.

(* As I desire to fully investigate the subject, I would regard it as a great favor if any person who knows of any authentic instance of eye-memory would send me an account of it, addressed to the care of the Secretary of the Franklin Institute. Since this lecture was written I have received a communication from Mr. Francis Galton, in which he requests me to collect such instances in America, with a view to statistical comparison. C. G. Leland.)

NODAL ESTIMATION OF THE VELOCITY OF LIGHT.

By Pliny Earle Chase, LL.D.
Professor of Philosophy in Haverford College.

(Read before the American Philosophical Society, March 19, 1880.)

The accuracy of my approximation to the apparent semi-diameter of the Sun* is confirmed by the following kinetic considerations, some of which, though seemingly of great fundamental importance and character, have been generally overlooked.

1. Matter has been usually regarded as composed of discrete particles. This hypothesis enters even into the kinetic theory of gases. If it is true, all force must be transmitted from particle to particle, and time must, therefore, be required to overcome the inertia of masses.

2. Attraction and repulsion have been generally considered under the influence of central forces, varying inversely as the squares of the distances from the centres and, therefore, producing motions with variable velocity.

3. Waves, orbital undulations, and other cyclical motions, are generally propagated with uniform or nearly uniform velocity, although they are often accompanied by subordinate movements with varying velocity. Variable velocities are often converted into uniform or nearly uniform velocities, as in the case of conical pendulums, planetary rotations and orbital revolutions.

4. In all undulations, and in all cyclical motions through an undulating medium, there are tendencies to synchronism. The synchronism may be complete, producing equal cyclical motions in equal cyclical times, or nodal, producing harmonic series of cyclical motions which are completed in equal times.

5. Newton showed that if a centripetal force varies as the distance of a body from the centre, all bodies, revolving in any planes whatsoever, will describe ellipses and complete their revolutions in equal times;† that bodies which move in right lines, running backwards and forwards alternately, will complete their several periods of going and returning in the same times;† and that if a fluid be composed of

* *Proceed. Am. Phil. Soc.*, xviii, 380.

† *Principia*, B. I, Prop. 47.

particles mutually repelling each other, and if the density varies as the compression, the centrifugal forces of the particles will be reciprocally proportional to the distances of their centres,* as if indicating a reaction against a force which varies as the distance from the centre. The centripetal force is partially illustrated by the rotation of planetary bodies; the centrifugal, by the varying pressure of elastic atmospheres.

6. Such centripetal force as is above supposed requires, for its complete manifestation, an omnipresence of activity, which is devoid of inertia, of ponderability, and of all other ordinary tests of material nature; an activity which may, perhaps, properly be regarded as spiritual.

7. Laplace found himself obliged to recognize an activity in gravitation, which is propagated with at least 100,000,000 times the velocity of light.† This activity, he says, may be properly regarded as instantaneous. If it is spiritual, it may without difficulty be regarded as absolutely instantaneous throughout the universe. If it is material, it is difficult to conceive of any relation of elasticity to density which would be so great as 10,000,000,000,000,000 times that of the supposed luminiferous æther. Yet such are the requirements of the Newtonian law, that "the velocities of pulses propagated in an elastic fluid are in a ratio compounded of the subduplicate ratio of the elastic force directly, and the subduplicate ratio of the density inversely."‡ The importance of this law has been shown by the investigations of Graham, by the inquiries of English and German physicists into the relations between electro-magnetic and luminous velocities, and by my own correlations of the force of solar rotation with the forces of light, gravitation and chemical attraction.

8. In any elastic or quasi-elastic medium, "if the distances be taken in harmonic [or arithmetical] progression, the densities of the medium at those distances will be in a geometrical progression."§ I use the term "quasi-elastic," in order to meet the views of Faraday, Preston‖

* *Ibid.*, B. II, Prop. 23.

† *Mec. Cel.*, X, vii, 22.

‡ *Principia*, B. II, P. 48.

§ *Ibid.*, B. II, P. 22.

‖ *P. Mag.*, June, Sept., 1877. Preston does not give Maxwell's demonstration of the ratio $\sqrt{\frac{5}{9}}$, and neither he nor Maxwell seems to have been aware that I had used

and others, who prefer to treat all kinetic questions in accordance with lines of force.

9. The distances of projection, under uniform resistance, are proportioned to the living forces of projection, and inversely as the density of the resisting medium.

10. In most, if not in all, physical investigations which introduce consideration of central force, velocity may be treated as a function of radius, time and mass.

$$v = F(r, t, m).$$

In undertaking to investigate successive conversions of spiritual, undulatory and centripetal or centrifugal energy, astronomical phenomena furnish the most abundant, extensive and varied opportunities for observation and illustration. Unfortunately, there is so much uncertainty in regard to the dimensions and densities of the principal heavenly bodies that we can point to few results which are so precise as would be desirable. There are, however, some important indications of the operation of the foregoing laws, which are confirmed by terrestrial phenomena that are capable of very accurate measurement.

In Searle's *Outlines of Astronomy*, page 403, the following figures are quoted from the *Annalen der Sternwarte in Leiden*, on the authority of Kaiser. "The apparent diameter of Mercury, at a distance equal to the semi-axis major of Earth's orbit, ranges, according to different observers, from 5·2″ to 6·9″; that of Venus from 16·6″ to 17·9″; the apparent equatorial diameter of Mars from 9·6″ to 9·2″; its apparent polar diameter from 9·4″ to 9·2″. Similar disagreements appear in different estimates of the apparent diameters of Jupiter, Saturn, Uranus and Neptune, at a distance for each planet equal to the semi-axis major of its orbit. Thus the equatorial diameter of Jupiter ranges from 39·5″ to 37·1″; its polar diameter from 37·9″ to 35·1″; the equatorial diameter of Saturn from 18·5″ to 16·9″; its polar diameter from 16·8″ to 15·1″; the diameter of Uranus from 2·9″ to 3·6″; that of Neptune from 2·5″ to 4·4″.

Kaiser adopts, as most probable values for the ratios of the several

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the same ratio of *vis viva* five years previously, in discussing results of gaseous energy (*Proc. Am. Phil. Soc.*, Feb. 16, 1872, vol. xii, p. 394, foot-note). I showed that in the explosion of gases, the secondary centre of oscillation, on the return towards the centre, is at $\left(\frac{12}{18} - \frac{2}{3} \text{ of } \frac{12-9}{18} = \frac{5}{9}\right)$ of the extreme excursion.

diameters to Earth's diameter, figures which I have increased by one per cent., in order to adapt them to more recent estimates of Sun's distance. These increased figures are given under r(I), in the following table. Under r(II) and in the subsequent columns, I give theoretical values which illustrate simple harmonic deductions from the above general function of velocity.

	Mass-denominator.	r(I).	r(II).	ρ.		g.	δ.
1. Mercury,	4865751	·34	·36	·387	$\rho^{\frac{3}{4}}$	= ·53	1·484
2. Venus,	427240	·97	·98	·723	$\rho^{\frac{3}{4}}$	= ·81	·822
3. Earth,	330985	1·00	1·00	1·000		1·00	1·000
4. Mars,	3093500	·53	·53	1·524	$\frac{1}{2}\rho$	= ·38	·719
5. Jupiter,	1047·88	11·04	11·02	5·203	$\frac{1}{2}\rho$	= 2·60	·236
6. Saturn,	3501·6	9·10	9·20	9·539	$\rho \div \rho^1$	= 1·12	·121
7. Uranus,	22600	3·60	3·60	19·184	$\rho \div t$	= 1·13	·314
8. Neptune,	19380	5·80	5·84	30·034		·50	·086
9. Sun,	1	109·11	109·05			27·83	·255

The value which I have assumed for Earth's mass is the one which I have deduced from velocities of rotation and revolution and Struve's constant of aberration. The other mass-denominators are the ones which are now generally adopted by astronomers. The semi-axes major are represented by ρ; the superficial equatorial acceleration of gravity by g; the density by δ; Earth's values being assumed as the units. In the expressions for g of Saturn and Uranus, $\rho_1 = 8{\cdot}539$; $t = 16{\cdot}9823$; ρ_1 being the mean distance between the centre of the belt of greatest condensation (Earth) and the primitive centre of rotary inertia (Saturn); t being the ratio between the time of Earth's rotation (a sidereal day) and the limiting time of satellite-revolution $\left(2\pi\sqrt{\frac{r}{g}}, \text{ at Earth's equatorial surface}\right)$. It is impossible, at present, to assign any more probable values for the planetary radii than those which I have given under r(II). From those values and the masses, g and δ are readily found by the proportionalities, $\delta \propto m \div r^3$; $g \propto m \div r^2$. The relations of g to simple functions of the semi-axis major would be very striking, even if they were only approximately true. Although we cannot ascertain whether the relations are exact or not, the following considerations seem to increase the probability that they are correct indications of normal harmonic modifications of gravitating force by distance and time.

In comparing the gravitating force at the principal centres of early nebular activity, we may, then, acknowledge a strong probability:

1. That the force at the centre of reciprocity (Neptune) is one-half as great as at the centre of the belt of greatest density (Earth).

2. That the force at the centre of rotary inertia (Saturn) is to the force at the centre of density as the rotary centripetal force at Sun is to the rotary centripetal force at Earth, the rotating tendencies being referred to Saturn as a centre.

3. That the force at the centre of nebulosity (Jupiter) is to the force at the centre of density as the combined influence of the gravitating force at the centre of reciprocity and the rotary centripetal force at Jupiter is to the combined influence of the corresponding forces at Earth.

4. That the force at the centre of nucleation (Sun) is equal to the velocity of light divided by the time of a half-rotation, the half rotation indicating the alternate oscillation of equatorial particles, from and towards the centre of gravity of Sun and Jupiter.

In extending the comparison to the subordinate centres within the belt of greatest condensation, we find a like probability:

5. That the force at Mars is to the force at the centre of density as the combined force of gravitating *vis viva* at the centre of reciprocity and rotary centripetal force at Mars is to the corresponding combined influences at Earth.

6. That the force at each of the inferior planets (Venus and Mercury) is represented by the ratio of projectile living forces to times of revolution.

Leaving the outer and somewhat doubtful territory and entering upon surer ground, let us consider some of the obvious results of conversion of primitive force with reference to centres of condensation.

1. If the velocity is constant the radius of rotation or revolution must be proportioned to the time.

2. If radii, which were originally established by a constant velocity, are converted into radii of free revolution under equivalent central forces, the times of revolution must be proportioned to the $\frac{3}{2}$ power of the radii.

3. If radii of synchronous revolution and axial rotation are due to the action of a primitive constant wave-velocity, while nucleal radii are due to the collision of particles moving with parabolic velocity, the

former velocity would be communicated in the time of a half-rotation, while the latter would be communicated in $\frac{\sqrt{2}}{\pi}$ of the same time.

4. Let us suppose that the ratio of the solar year to the terrestrial day originated in the constant velocity (1) of light, which is still represented by the equation of solar half-rotation $\left(\frac{gt}{2} = v_\lambda\right)$; that the time-radii ($r_t$) were converted into radii of free revolution under equivalent central forces (2), and that corresponding nucleal radii (ρ_t) were established by parabolic collision (3). We should then have

$$\left(\frac{r_t}{\rho_t}\right)^{\frac{3}{2}} = \frac{\pi}{\sqrt{2}}$$

or, substituting the ratios which are represented by r_t and ρ_t,

$$\left(\frac{1 \text{ year}}{1 \text{ day}}\right)^{\frac{3}{2}} : \left(\frac{\text{Earth's semi-axis major}}{\text{Sun's semi-diameter.}}\right)^{\frac{3}{2}} :: \pi : \sqrt{2},$$

The sidereal year is composed of the original nebular sidereal rotation and the 365·25636 additional sidereal rotations which are due to terrestrial condensation. Making these substitutions,

$$\left.\begin{array}{l}(565{\cdot}25636)^{\frac{3}{2}} : x^{\frac{3}{2}} :: \pi : \sqrt{2} \\ x = 214{\cdot}5365\end{array}\right\} \quad \ldots\ldots A.$$

Among the obvious nodal influences of distance and velocity which may be reasonably supposed to have modified the kinetic undulations between the centres of density and of nucleation, the following may be specified:

1. The velocity of light, V_λ, or the projectile velocity which is equal to the sum of Sun's gravitating equatorial reactions during a half-rotation, $\frac{gt}{2}$.

2. Sun's limiting velocity of revolution, $V_0 = \sqrt{gr}$, r being the equatorial radius.

3. Earth's limiting velocity of revolution, $v_0 = \sqrt{gr}$, at the equatorial surface.

4. Earth's superficial equatorial velocity of rotation, v_r.

5. Earth's semi-axis major, ρ_0.

6. Earth's diameter, $2r$, or the major-axis of limiting synchronous linear, elliptical and circular oscillation.

7. Moon's semi-axis major, ρ_1.

8. The ratio of variation between Laplace's limit, r_1, and the nucleal radius, r_0; $r_1 \propto r_0^{\frac{4}{3}}$.

From Struve's constant of aberration, equation *A*, and other well-known measurements, we find : $V_\lambda = 214{\cdot}5365r_0 \div 497{\cdot}827 = {\cdot}4309458r_0$; $V_0 = 214{\cdot}5365^{\frac{3}{2}} \times 2\pi r_0 \div 31558150 = {\cdot}00062564r_0$; $v_0 = \left(\frac{3962{\cdot}82 \times 32{\cdot}088}{5280}\right)^{\frac{1}{2}} = 4{\cdot}9075$; $v_r = 2\pi \times 3962{\cdot}82 \div 86164 = {\cdot}288974$; $V_\lambda \div V_0 = 688{\cdot}815$; $v_0 \div v_r = 16{\cdot}98237$. The combined nodal action of V_λ, V_0, v_0, v_r, ρ_0 and $2r$ are represented by the equation:

$$\left.\begin{array}{l} \dfrac{V_\lambda}{V_0} \div \dfrac{v_r}{v_0} = \dfrac{\rho_0}{2r} \\ 688{\cdot}815 \times 16{\cdot}98237 = \rho_0 \div 7924{\cdot}64. \\ \rho_0 = 92{,}711{,}850 \text{ miles.} \\ V_\lambda = \rho_0 \div 497{\cdot}827 = 186{,}233 \text{ miles} = 299{,}705 \text{ kilometres.} \\ r_0 = \rho_0 \div 214{\cdot}5365 = 432{,}495 \text{ miles.} \\ \rho_0 \div r = 23{,}395{\cdot}4. \\ \dfrac{\text{Sun's mass}}{\text{Earth's mass}} = 330{,}997. \end{array}\right\} \quad B.$$

If we adopt Newcomb's estimates of Sun's diameter, mass and distance (*Popular Astronomy*, p. 528), the nodal value of V_λ would be 185,334 miles; the value, as determined by Struve's constant of aberration, 185,475 miles; the discrepancy being only $\frac{3}{400}$ of one per cent. Michelson's estimate (299·820 km.) is about $\frac{1}{26}$ of one per cent. greater than mine, and about $\frac{4}{9}$ of one per cent. greater than Newcomb's.

Newton's law of the ratio of elastic densities to distances (8), the law of projection under uniform resistance (9), and the ratio of variation between Laplace's limit and the nucleal radius, all are illustrated by the lunar equations:

$$\left.\begin{array}{l} \dfrac{v_0}{v_r} \times \dfrac{32}{9} r = \rho_1 = 60{\cdot}3815r. \\ \left(\dfrac{r_0}{v_r}\right)^{\frac{32}{9}} r = \rho_0 \textit{ very nearly} = 23{,}622r. \end{array}\right\} \quad . \; . \quad C.$$

J. J. von Littrow's estimate for Moon's semi-axis major, cited by Searle (p. 406), is 60·2778, or about $\frac{17}{1000}$ of one per cent. less than the

above result. The velocity of light, as deduced from the lunar value of ρ_0, is 188,040 miles, or nearly one per cent. greater than the value found in equation *B*.

I think no one will be likely to attach much weight to the larger value, but it is interesting on account of its indication of elliptical nebular influence, with a nucleal radius about one per cent. larger than Sun's present radius, and a major-axis about one per cent. larger than Earth's present mean vector-radius. The nebular influence may be inferred from the fact that $\frac{32}{9} = 2 \times \left(\frac{4}{3}\right)^2$.

OF THE ADJUSTMENT OF A QUADRILATERAL IN A TERTIARY SYSTEM OF TRIANGULATION.

By T. W. Wright,
Assistant Engineer U. S. Lake Survey, Detroit, Mich.

In a quadrilateral *ABCD* the eight single angles at the vertices are equally well measured; required to adjust it so that the sums of the angles of the four triangles into which it is divided by the two diagonals shall each $= 180°$.

It follows, from ordinary geometry, that if the sums of the angles of three of the triangles $= 180°$, the sum of the angles of the fourth triangle must $= 180°$.

Assume the eight measured angles $A_1\ A_8\ B_2 \ldots$ as approximate values, and call $a_1\ a_8\ b_2 \ldots$ the most probable corrections to these values.

Then the equations of condition are

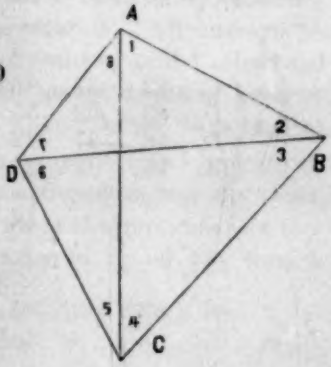
$$A_1+a_1+B_2+b_2+B_3+b_3+C_4+c_4=180$$
$$B_3+b_3+O_4+c_4+C_5+c_5+D_6+d_6=180$$
$$C_5+c_5+D_6+d_6+D_7+d_7+A_8+a_8=180$$

or

$$a_1+b_2+b_3+c_4=v_1$$
$$b_3+c_4+c_5+d_6=v_2$$
$$c_5+d_6+d_7+a_8=v_3$$

with the minimum equation

$$a_1^2+a_8^2+b_2^2+b_3^2+c_4^2+c_5^2+d_6^2+d_7^2=\text{a minimum.}$$



Solving in the usual way we find

$$a_1=b_2=\frac{1}{4}v_1-\frac{1}{4}v_4$$

$$b_3=c_4=\frac{1}{4}v_1+\frac{1}{4}v_4$$

$$c_5=d_6=\frac{1}{4}v_3+\frac{1}{4}v_4$$

$$d_7=a_8=\frac{1}{4}v_3-\frac{1}{4}v_4$$

where

$$v_4=-\frac{1}{2}v_1+v_2-\frac{1}{2}v_3$$

Hence the rule

1. Write the measured angles in order of azimuth in two sets of four, the first being the angles of the triangle ABC and the second those of CDA.

2. Adjust the angles of each set by $\frac{1}{4}$ of the difference of their sums from 180°, arranging the adjusted angles in two columns, so that the first column will show the angles of ABD and the second those of BCD.

3. Adjust the first column by $\frac{1}{4}$ of the difference of its sum from 180° and apply the same correction with the opposite sign to the second column.

The final angles will then result.

Example:

		Measured angles.			First adjustment.		Final adjustment.
$\measuredangle ABC$	A_1	32°	05′	40″	39·0″		38·75″
	B_2	74	25	05	04·0		3·75
	B_3	44	12	04		3·0	3·25
	C_4	29	17	15		14·0	14·25
				4			
$\measuredangle CDA$	C_5	22	37	46		46·5	46·75
	D_6	83	52	55		55·5	55·75
	D_7	58	27	42	42·5		42·25
	A_8	15	01	35	35·5		35·25
				58	1·0		00·

APPROXIMATE QUADRATURES OF THE CIRCLE. III.

By Pliny Earle Chase, LL.D.

A late number of *Dingler's Polytechnisches Journal* (March, 1880, pp. 400–1) contains an approximate construction of the ratio of the circumference of a circle to its diameter by L. Hajnis, of Prague. It is not so simple as my first method,* and the result (3·141738) give an excess of ·000146 diam., which involves an error nineteen times as great as that of my first construction, and more than 540 times as great as that of my construction of the ratio of Adrian Metius.†

A previous number of *Dingler's Journal* (1879 **232** 182) gave an approximation which had been simultaneously and independently discovered by Hajnis and by Dr. J. G. Wiedemann, of St. Petersburg. The comparative closeness of the European and American methods is shown below:

		Error.	Ratio of Error.	
1. Wiedemann-Hajnis,	3·141421	—·000171	633	
2. Hajnis, . .	3·141738	+·000146	541	European.
3. Mean of 1 and 2,	3·141579	—·000013	48	
4. Chase, I, . .	3·141585	—·00000766	28·3	
5. Perkins, .	3·1415922	—·00000045	1·6	American.
6. Chase, II, .	3·1415929	+·00000027	1	

Some of the readers of the journal seem to have thought that my second construction was borrowed from Metius. Such is by no means the case. He merely discovered the fractional approximation, and geometers have striven in vain, for 250 years, either to find a simple construction for this approximation or to devise some other construction which would give a result nearly as accurate. All attempts in the first-named direction seem to have been fruitless until I solved the problem; and few of the methods in the second direction, even of those who have thought their solutions rigidly correct, have been so satisfactory as to deserve a place in such a comparison as I have given above. The construction by Perkins was ingenious, and far closer than any which had preceded it, but it was too complicated for any practical purpose. It would be much easier to lay off $\frac{355}{113}$ from a

* This Journal, July, 1879, p. 45. † *Ibid.*, Aug., 1879, p. 105.

scale of equal parts than to go through all the details of his method, and the result would probably be more satisfactory.

For combined simplicity and accuracy sufficient for all practical purposes even my first construction still challenges competition. The second, I think, will long remain an *Ultima Thule* for all who like to amuse themselves with geometrical approximations of this kind.

Since writing the above I have seen a neat and simple approximation by Josef Baader (*Dingler's Journal*, 1880 **236** 258), which gives ·7854004 D^2, the true area of the circle being ·78539816 D^2. The error is, therefore, less than ·0003 of one per cent. This is nearly as close as my first approximation, but the error is more than 30 times as great as that of my second construction.

If the quadrature is desired, instead of the rectification, it may be readily obtained as follows: Referring to the figure (Aug., 1879, p. 105), extend AC to C^1, making $AC^1 = 2\,AC$; on AC^1 take $AF^1 = AF$; join FC^1; draw F^1H parallel to C^1F. Then $AH^2 = ·78539823\,AF^2$.

Chicken Cholera.—Pasteur finds that the germs of chicken cholera increase with marvelous rapidity in a chicken broth, neutralized by potash and rendered sterile by a temperature of from 110° to 115° (230° to 239°F.). If the point of a needle be dipped into a virulent broth the prick of the needle will be fatal to chickens, but it produces merely an abscess in Guinea pigs. The virulence may be diminished by retarding the development of the germs, and inoculation does not then become fatal, but it produces a temporary disorder which, like vaccination, serves as a guard against subsequent attacks.—*Comptes Rendus.* C.

Photography of the Heat Spectrum.—Abney has made a photographic chart of the portion of the solar spectrum which is less refrangible than the line A. It was obtained by a reflecting network, of about 1½ inches opening, and containing 17,200 lines per inch, with a special preparation of silver, which seems sensitive to all radiations. The result agrees with the thermal observations of Lamansky, and also, so far as comparisons have been made, with those of Sir John Herschel. Since the construction of the chart Abney has obtained photographic proofs of solar and artificial spectra which extend beyond the wave-length 19400. A complete description of his processes is to be published by the Royal Society.—*Compt. Rend.* C.

EARLY USE OF ANTHRACITE COAL IN PENNSYLVANIA.

[The following article has been kindly handed to us by Mr. Washington Jones for publication in the JOURNAL. He received it from Mr. John T. Morris, in whose possession it has been, we believe, for a long time. The original writer of the article cannot be discovered at this period, but the ink, faded with time, and the old-fashioned paper attest to the age of the document, which is of great interest if only to show the immense progress that has been made since that time. N.]

In 1824 Jonah and George Thompson, of Philadelphia, made arrangements for the construction of a new steam engine, expressly calculated for the use of anthracite coal, at their iron works on the Schuylkill, 26 miles from Philadelphia; its power was estimated equal to 100 horses.

In January, 1825, it was completed and in successful operation, and no other fuel was used, except small wood for kindling, for upwards of two years that they had possession of the works.

Before their trial they resorted to every means to obtain information whether the coal had been previously used for the purpose either in this or the neighboring States, and the result was that, although many experiments had been made, yet in every instance it had been attended with disappointment and consequently abandoned.

This object (which succeeded on the first trial) was accomplished by dividing the furnaces under the four boilers, of 22 feet each, by a centre wall, making each about 10 feet deep, and having doors at the end; the flues passed into a high chimney in the centre, the draft regulated with a damper, and the grate bars placed much nearer the bottom af the boilers than what is required for other fuel.

The enclosed extract from the West Chester paper, by C. Miner, although the date is not attached, was published without the knowledge of the proprietors:

"We understand that the Messrs. Thompson, at the Phœnix Nail Works, on French Creek, have fully succeeded in constructing a furnace for a steam engine calculated for the use of anthracite coal, and in discovering a mode by which this fuel may be most advantageously applied to that important purpose. We would heartily congratulate the eastern section of our State upon this valuable discovery. Noth-

ing within our knowledge has occurred of recent date which can have a more auspicious influence upon our manufacturing interests. The difficulties which have heretofore been by some supposed insurmountable in the way of using our hard coal for steam engines, have arisen from the intensity of the heat which it gives out in a full state of ignition—its sluggishness in kindling, and the partial suppression of the fire when fresh supplies of coal were added. These difficulties have, as we are assured, been thoroughly conquered by the perseverance and ingenuity of the gentlemen whose names we have taken the liberty to mention. Their success has been complete, and they are therefore entitled to the praise of having conferred upon the community a benefit of incalculable general importance. No one will doubt this who will take the trouble to reflect upon the consequences which have resulted to other countries from the possession of a cheap and abundant fuel for the use of steam engines and other similar purposes. This may emphatically be said to be one of the mainsprings of England's greatness. It is this, too, which has largely contributed to make Pittsburg, which, within the recollection of many a one now living, was but a military station in the western wilderness, one of the first manufacturing towns in our wide spread territory. The same cause, when brought fully into action in our own district, must produce similar effects upon the places within the range of its influence; and especially upon Philadelphia, where mechanical power to any extent, and in almost any situation, can be easily created at a moderate expense. Machinery worked by steam power may be expected to abound among us, thereby producing a consumption of thousands of tons of coal annually. Who can calculate the benefits to result from such a state of things? It will affect the value of our coal lands within a convenient distance from the navigation. It will give constant and profitable employment to a large body of colliers, boatmen and others engaged in mining and transporting the coal. It will secure to the Schuylkill Navigation Company a prolific source of revenue from their tolls. It will encourage and promote the undertaking of similar public works, canals and railroads in the other coal districts with which our State abounds, and especially those which are tributary to Philadelphia. It will open to that city a vast field for the employment of her capital and industry, to the augmentation of her trade and population. These great advantages, so diffusive in their prosperous results, the Schuylkill Navigation will enable us to realize from a

sterile and mountainous country, formerly considered almost worthless. Let such considerations stimulate our people to a never-tiring zeal in that cause which should be so near to the heart of every patriotic citizen—the cause of internal improvement."

On the 23d of July, 1829, the writer perfected numerous experiments relative to increasing the blaze of anthracite coal by the introduction of steam into a furnace; it had the effect to a very great extent; but whether the chilling of the furnace will not counterbalance the effect of the increased flame can only be decided by further trials.

The moist blasts in England are now entirely abandoned in the furnaces from the consequent loss of caloric.

Under any circumstances no other difficulty exists in the use of anthracite coal for steam power but its price in comparison with Virginia bituminous coal and wood.

It is understood that the experiment made in Baltimore for introducing steam into the furnace to increase the blaze was in a fire made of bituminous coal and not of anthracite, and the application of it to anthracite and the effects produced was for the first time ascertained in the experiment hereto annexed.

The Messrs. Thompson furnished patterns and information which were applied to the construction of the steam engine used on the Union Canal when the anthracite was employed.

Prediction of Chemical Elements. — In awarding the L. Lacaze prize to Boisbaudran, for the discovery of gallium, the committee remark that the new element was not obtained by accident or by any spectroscopic indications. Its discoverer was led, by theory, to seek, in ores of zinc, an element which was required in order to fill a vacancy in his classification. By operating upon 52 kilogrammes (114·64 lbs.) of blende he succeeded in obtaining one-hundredth of a milligram (·000154 grain) of gallium; in other words, in order to obtain a unit of gallium he was obliged to use five thousand million units of blende. By pursuing his investigations Boisbaudran found that there was a very close agreement between the properties of gallium and those which had been previously announced by Mendelejeff, as belonging to a metal which was required to fill a vacancy in his classification.—*Comptes Rendus.* C.

ON THE ADHESION OF BELTS.

By J. H. Cooper.

The driving power of belts, by which we mean the holding on to, the adhesion, or that which imparts motion to a belt while in contact with a revolving pulley, has been attributed to several causes, to one of which I wish in this short article to refer—that of atmospheric pressure. It is called to mind now by reading some articles in late issues of scientific papers, which lay great stress upon the efficacy of this means of creating adhesion. This announcement is much like that startling physiological statement of the many tons of pressure imposed upon the human body by the atmosphere, which is very taking to the sense until better known.

A belt has a movement to and from a pulley with perfect freedom, regardless of the atmosphere, *touching* it as its form, pliability and strain permit, and *holding* to it according to the interposed unguent, adhesive, or viscous substance, which has been spread over the surface of belt and pulley.

The kind of intermedia used has much to do with the driving power of belts. If fine lubricating oil be employed on clean surfaces of belt and pulley, it will effectually exclude the air from the surface of contact, but the driving power will be reduced to a minimum, if there be any at all transmitted. If dry dust of yielding material be employed on clean surfaces of belt and pulley, then, indeed, will the air with the dust diminish driving power.

There are conditions of belt driving where it is alleged the interposed film of air *lessens* adhesion. Upon this Rankine says: "It is well known through practical experience that a belt for communicating motion between two pulleys requires a greater tension to prevent it from slipping when it runs at a high than at a low speed. Various suppositions have been made to account for this, such as that of the adhesion to the belt of a layer of air, which at a very high speed has not time to escape from between the belt and the pulley. But the real cause is simply the centrifugal force of the belt, which acts against its tension, and therefore slackens its grip of the pulleys."

In collecting "belting facts and figures" during the last score of

years, for my own use, I met with several statements asserting with considerable confidence the doctrine of "suction" as the chief cause of attachment between pulley and belt, but I could not find anywhere written a fair statement of reasons why such a force did or did not act according to the circumstances of belt driving, nor could I discover any appeal to experiment, which by removing the atmosphere, putting suction outside the apparatus (as it were), and thus settling once for all the value of vacuum for belt driving.

It is very true that if the belt does not touch the pulley it cannot pull it around, nor can it be driven by the pulley. It is also true that if belt and pulley touch on a limited area only, each can drive the other with a force, but a part of what it is capable of doing, and it is only when contact is made perfect, that is when every square inch of the belt, so to speak, is down solid on the pulley surface, which surface we will grant is very smooth, that the greatest driving effect is obtained.

In practical proof of the necessity of contact and exclusion of air, I offer the accidental discovery of a correspondent of the Boston *Journal of Commerce*, March 5th, 1880:

"Some time since I was running an Andrews pump No. 4, elevating water through a 6-inch pipe 22 feet high, driving the spindle with an 8-inch belt on a pulley 12 inches diameter; 825 Rpm.

"The pulley was on the under side of the belt. I was greatly troubled with slipping and 'squealing' of the belt. Not wishing to run the belt any tighter, I ordered three rows of holes, $\frac{1}{8}$ of an inch diameter, $2\frac{1}{2}$ inches distance on the circumference, to be drilled, preparatory to facing with leather and rivets through the holes. Not being able to finish the job immediately, the belt was put on, and greatly to our surprise worked without slipping or 'squealing' at all, perfectly noiselessly. *The air was let out through the holes.*"

These things being so, are we yet warranted in concluding that the imparting of motion from belt to pulley and pulley to belt is all the work of the air, or, rather, the effect of its absence from the region of contact and the presence of it on opposite sides of belt and pulley?

Again, is the driving of the belt in the same direction as that in which the suction is felt? Now mark, the atmospheric resistance becomes sensible by pulling at *right angles to a plane surface of joint which does not admit air;* release the pull and try to slip the piece used for testing (which may be of wetted leather of handy size) over

the surface to which it is applied; it moves freely in every direction, offering no resistance, possessing no adhesion, being, in fact, in equilibrium, and by lifting one edge can be raised wholly away with ease.

The power of the belt does not move in lines at right angles to its contact with the pulley face, but tangent to the pulley circle, parallel to the face of contact; as we slip the *sucker* freely on the flat, wetted surface, so the belt slides on the pulley face, there is no atmospheric pressure manifest in either case.

But has any one tested this matter in a vacuum and made record of the results gained? I have; and if you allow me I will quote from "Use of Belting" what I said about this several years ago:

The adhesion of belts to pulleys is frequently attributed to the pressure of the atmosphere, and in order to show how much the air influences belts in this particular, the following simple experiments are presented:

Take a circular disc of leather, say 3 or 4 inches diameter, with knotted string secured in its centre, and, when well water-soaked, press it upon any level wetted surface. The "boys" call this apparatus a "sucker," and it well illustrates the phenomenon of atmospheric pressure, or "suction," as it is usually called.

If an effort be made to draw it away from this surface by the string, it will be found resisting very forcibly, but the gentlest pressure will slide it on the wetted surface; it does not offer the slightest opposition to motion in the direction of its face, nor will it resist removal if raised first at the edge and then peeled off.

The atmosphere does not press two bodies together when it can get between them; it is only when excluded by a tight joint that the development of its pressure is possible, and it becomes sensible only when an effort is made to separate them by a force acting at right angles to the plane of their faces.

Another simple experiment shows that when two level, smooth and clean surfaces come together by a motion like the closing of a book—which is similar to that of a belt coming in contact with its pulley—there will be retained between the two a thin film of air, and, while this remains, the contact of the two is imperfect, and the sliding of one over the other is easily performed. Take two iron "surface-plates," which have been scraped down to a practically perfect plane, and lay one of these on the other, like a belt goes to a pulley; they will be found not in contact at all, but as if floating one on the other, and the

top one will slide off by its own weight at the least inclination of the lower one.

Much of this interposed film of air can be displaced by a sliding of one plate on the other, starting, say at one corner, with the plates in close contact, and carefully pushing one over the other, holding it the while close to, as if to keep the air out. Then, indeed, an obstinate resistance to sliding will be felt, and the friction of nearer contact will be made thoroughly sensible.

But this way of bringing surfaces into contact has nothing to do with belt action, except to prove the need of a plastic surface on belt and pulley, which will enable them to adhere, while in contact, with sufficient force to prevent sliding, and at the same time be uninfluenced by the intermedium of air.

And lastly, in order to put the matter to actual test, an apparatus was constructed, such that a leather belt was made to slide on the face of a smooth iron pulley, and also to drive the same iron pulley up to slipping of the belt. In both cases the adhesion or driving power of the belt was held by a spring balance, so the work of the belt could be observed.

Experiments were tried with this mechanism placed in a bell glass jar on an air pump plate, with and without air in the jar, and if any difference was observed in the adhesion of the belt to the pulley it had more in vacuum than when the atmosphere was present.

Effect of Use upon the Quality of Iron.—In the summer of 1878 Prof. Bauschinger superintended some repairs upon a chain bridge which had been built in 1829. He examined several of the links by various tests, and found that there was no evidence of any diminution in the strength of the iron, nor of any change in its structure or its elasticity during the use of nearly half a century to which it had been subjected. In 1852 von Pauli tested several bars for another bridge, which was repaired in 1878, when Bauschinger subjected some of the same bars to new tests. He found that the mean strength was still the same, after twenty-five years' use, and that no change of structure appeared to have occurred since the time of von Pauli's original tests. —*Dingl. Jour.* C.

The Brush Machine in England.—The competitive trial of dynamo-electric machines by the Franklin Institute has been turned to good account by the proprietors of the Brush machine, who have lately introduced it into England. The correspondent of a French journal states that with 13½ horse-power it maintains 16 lamps, each having a luminous capacity of 1000 standard candles. He pronounces this the most satisfactory result which has yet been attained.—*Chron. Indust.* C.

Yeast vs. Phylloxera.—The recent investigations of Hagen on the destruction of obnoxious insects by application of the yeast fungus have awakened some discussion in the French Academy, in view of the failure of all the plans for destroying the phylloxera. Some members of the commission have recommended the withdrawal of the prize of 300,000 francs ($60,000). The perpetual secretary, however, urged a series of experiments similar to Hagen's, and it has been decided to continue the prize.—*Comptes Rendus.* C.

Fire- and Waterproof Paper.—Mix one-third of ground asbestos fibre with two-thirds of paper paste in a solution of common salt and alum. Pass the mixture into a machine, plunge the paper thus made into a bath of dissolved gum lac and send it through the finishing rolls, when it may be cut into sheets. The salt and alum increase the strength of the paper and its resistance to the action of fire. The lac renders it impermeable to moisture, without interfering with its fitness for the reception of ink.—*Les Mondes.* C.

Chemical Use of Glucose.—According to Böttger there is no method for reducing the salts of silver so convenient and so sure as the use of glucose in alkaline solution. Take, for example, chloride of silver freshly precipitated and well washed, suspend it in a sufficient quantity of diluted caustic soda, and add a small portion of glucose; in a few minutes, upon boiling, the reduction takes place. The silver can be collected, washed and slightly calcined, in order to obtain the metal pure, under the form of a light sponge of a dull white. The same method furnishes an exceedingly active platinum black, and with the salts of copper it gives an oxide of a very beautiful red.—*Chem. Zeit.* C.

Spectrometric Measurement of High Temperatures.—Crova has devised an instrument which he calls *spectropyrometer*. It consists of the combination of a direct-vision spectroscope, a collimator and dispersive prisms, and a graduated circle for determining the degree of rotation which is necessary to equalize the incandescent light with that of a standard lamp. It furnishes the means for accurate measurements, from all temperatures between 580° (1076°F.) and the highest possible temperatures.—*Comptes Rendus.* C.

Spontaneous Generation.—Bastian has again visited Paris in order to try to demonstrate his views with regard to spontaneous generation. Being unable to come to any agreement with Pasteur as to the manner of conducting his experiments, he decided to return to London. But before setting out he described his operation in detail, and Pasteur asked him how he cleansed his retorts. He replied "by rinsing them with very pure water." Pasteur assured him that there were bacteria even in the purest water, and advised him to repeat his experiments after having heated all the apparatus thoroughly in the fire. Nothing has since been heard of spontaneous generation.—*Les Mondes.* C.

Office of Chlorophyll.—By concentrating solar light on vegetable tissue, under a microscope, Pringsheim has conducted a series of "microphotochemic" observations upon the chlorophyll and protoplasmic contents of the living cell. The absorption of oxygen increases with the intensity of the light, and especially with the intensity of the chemical rays. But the increasing intensity of the respiration finally becomes injurious by burning the combustible contents of the cell, and destroying the hypochlorine, which serves as a food for respiration. The light which is necessary for accumulating carbon, therefore, becomes hurtful as soon as oxidation exceeds assimilation. The chlorophyll, by its luminous absorption, helps to balance these two opposite functions. By its preference for the chemical rays it diminishes the respiratory effort, and thus acts as a protecting screen, so that even in the brightest sunlight the assimilation of carbon exceeds the oxidation of the carbonaceous products. Hence, contrary to the prevalent opinion, chlorophyll has no direct relation with the decomposition of carbonic acid, but it serves rather as a regulator of vegetable respiratory action.—*Comptes Rendus.* C.

Wollaston Prize.—The London Geological Society has awarded its great Wollaston medal to M. Daubrée, director of the school of mines, for his researches upon the artificial constitution of the materials found in aerolites and in the lavas ejected from volcanoes.—*Chron. Indust.* C.

Magnetic Rotation by the Atmosphere.—In a work which is not yet completed H. Becquerel has shown how to measure the magnetic rotatory power of certain gases, and especially of the atmosphere, at ordinary temperatures and pressures. He finds that the rotatory power of the air, for the yellow rays, may be represented approximately by 0·090128, the rotatory power of bisulphide of carbon for the *D* line being taken as the unit.—*Ann. de Chim. et de Phys.* C.

Hygiene of the Electric Light.—M. Javal, director of the ophthalmic laboratory at the Sorbonne, has been studying the hygienic influence of the daylight in schools and of various artificial lights upon the eye. He concludes, in accordance with many other competent savants, that the electric light, when suitably arranged, has no injurious influence upon vision, and that it possesses many advantages over the other methods of lighting which are now employed.—*Bull. du Mus. de L'Ind. de Belg.* C.

Compression of Gaseous Mixtures.—If five volumes of carbonic acid and one volume of air are compressed in a proper apparatus the carbonic acid readily liquefies. If the pressure is carried to 150 or 200 atmospheres the meniscus of liquefied acid is gradually effaced, and the liquid finally disappears. The tube then appears filled with a homogeneous matter, which resists all further compression, as a liquid would do. If the pressure is then gradually diminished the liquid suddenly reappears, at a pressure which is constant for fixed temperatures; a thick mist arises, vanishes in a moment, and marks the level of the liquid which has reappeared. The phenomenon cannot be explained by the heat of compression, for the tube is plunged in water which keeps it at a constant temperature, and the compression is made slowly enough for the cooling to be always complete. Cailletet thinks that the gas and liquid are mutually dissolved, so as to form a homogeneous compound. He has extended the experiments to a pressure of 450 atmospheres without varying the result.—*Compt. Rend.* C.

St. Gotthard Tunnel.—The length of the tunnel is 14,920 metres (9·27 miles), the breadth 6·5 metres (7·11 yards). The perforation has required seven years and five months (4½ years less than Mont Cenis). The average progress per day has been 5·5 metres (5·015 yards). The blasting has used 490,000 kilogrammes (1,302,821 lbs.) of dynamite. The total number of mining holes was about 320,000. There have been 1,650,000 drills, and 1,450,000 cartloads of material have been taken from the interior of the mountain.—*Les Mondes.* C.

Launching a Bridge.—In constructing a railroad bridge over the river Ranee, at Dinard in France, the engineer decided to build the bridge on the shore and then launch it over the river. The bridge weighed, when it was complete, 2,600,000 lbs.; its height above the river was 100 feet, and the span 314 feet. Twelve windlasses were used to draw the bridge into its place. It was supposed that four or five days would be sufficient for the work, but in consequence of the breaking of a chain two weeks were required.—*Der Techniker.* C.

A New Phenomenon of Magnetism.—It is well known that the ratio between the residual and the temporary magnetism of a bar of steel enveloped by a magnetizing coil diminishes as the bar becomes shorter and thicker. Aug. Kighi was led by theoretical considerations to a conclusion which is opposed to the ordinary phenomena, but which experience has confirmed in every particular. It is this: If we take bars of the same steel and of the same diameter, but of diminishing length, we finally reach a length which shows no magnetization, and with still smaller lengths we obtain a residual magnetism which is opposite to that of the coil.—*Comptes Rendus.* C.

Book Notices.

Trusses and Arches. By Chas. E. Greene, A. M., Prof. of Civil Engineering, University of Michigan. Part III, Arches. 190 pp. 8vo. John Wiley & Son, New York.

This last part completes Prof. Greene's discussion by graphical and analytical methods of the theory of trusses and arches, and may be said to present by far the most full and compendious text book on this subject yet published.

Throughout the work it is recognized, properly, that the graphical

representations are approximate exhibitions of the forces brought into play by supposed constructions, where the relations of lengths of certain lines drawn in certain directions are proved to be, within the limit of desirable accuracy, correct proportions for certain strains in such directions. And this recognition is accompanied by rigorous analytical demonstration, which gives the derivations of such lines and establishes the fact that, with perfect accuracy of drawing, these lines become absolutely correct. It is doubtful, however, if the expressed aim of the author—"to give the ability to intelligently design an arch to those not familiar with higher mathematics"—can be effected. The royal road to knowledge is not shortened by cross cuts. The student or the engineer who shall have so studied Prof. Greene's admirable and *short* treatise as to use it intelligently will have become familiar with the mathematics of the subject. It is possible that in the class in the University a student may be instructed touse the graphical methods independently, but unless the foundation be such that the reason for those methods remain for all time in the memory of the student, his application years afterwards will be likely to be more faulty than that of the wholly uninstructed mechanic who copies admitted excellent practice by a simple effort of visual appreciation, and modifies by empirical proportions to suit novel requirements. The constructor, whether engineer or contractor, who will fully meet a new demand in truss or arch construction will be safe to call to his assistance some one grounded in the elementary knowledge to be found in its best form in this book of Prof. Greene's, and not to trust to an imperfectly understood application of its rules. B.

PRACTICAL KERAMICS FOR STUDENTS. By C. A. Janvier. Square 12mo. New York: Henry Holt & Co., 1880.

In this work the talented authoress has given, in as small a compass as possible, a clear account of the manufacture and decoration of pottery of all kinds, the well known works of Jacquemart, Marryat, Birch and others having been carefully studied beforehand, and while she has devoted most attention to kinds of pottery that have a general interest, histories of it have been omitted, or only touched upon, from having appeared so often before, and illustrations of the machinery used, furnaces, etc., are not given, for the same reason. The fullest details seem to be with regard to modern pottery, Limoges wares and

the wonderful productions of the Chinese and Japanese artists, so eagerly sought for by all collectors. In the first chapter the nomenclature of the subject and depositions are given, followed by a brief historical sketch and an account of the materials that enter into this important manufacture. The various processes are then taken up, the preparation of the pastes, the shaping, glazing, firing, etc. An important chapter is then given on the decoration of porcelain. A description of the different wares then follows—soft pottery, hard and very hard—being the general divisions, and the remainder of the work is taken up with a treatise on keramic painting, æsthetic hints, etc. In an appendix we have a short bibliography of the subject (only a few authorities being mentioned), and a brief criticism of their works are given. The index, without which by a heavy penalty in law no book should be allowed to appear, is quite a full one, and admits of ready reference to any particular point.

The work is tastefully got up, and the cover highly artistic and attractive. The paper and the broad margin of the page are in the right direction, but we cannot help but think a lighter-faced type and less heavy impression would have made a more beautiful book. N.

DWELLING HOUSES: Their Sanitary Construction and Arrangements. By Prof. W. H. Corfield. 18mo. New York: D. Van Nostrand, 1880.

The great importance of the subject, and the interest manifested in all that pertains to the hygeine of our homes, was the reason of the republication of these lectures in their present form. After giving some directions as regards the situation and construction of a house that apply to our country as well as England, the important subjects of ventilation, lighting and warming are taken up. The author believes that the use of coal in our houses will cease almost entirely, and the proper use of gas will be found in heating apartments, cooking, etc., stoves for this purpose being highly commended for their convenience and cleanliness, the products of combustion being of course removed. The remainder of the work is taken up with the question of sewerage, ventilation, etc.

The eminence of the author, and his high reputation as a writer, particularly qualify him to speak intelligently on these subjects, and his work is worthy of a careful study by all interested. N.

TIN MINING IN LARUT. By Patrick Doyle, C. E. With maps, plates, etc. 12mo. London: E. & F. N. Spon, 1879.

This little book has been reprinted from the *Mining Journal*, and is the result of notes made during the author's connection with the mines, and data obtained from the most reliable mine owners in Larut, and is accordingly very interesting. The author states that the whole of the land lying along the base of the Larut ranges is more or less stanniferous, and that the strip is in length about fifty miles, with an average breadth of six miles. The tin beds are composed of granitic rocks mixed with the ore, the crystals (peroxide of tin) varying from that of fine sand to the ordinary quartz pebbles. There are eighty mines in operation, owned by forty firms, employing on an average eighty-six men in each mine. As the Chinese are slaves of custom, and everything is done by precedent, they are much averse to improvement; and yet in one of the largest of the mines a centrifugal pump and engine has been introduced in place of the comparatively useless Chinese water wheel, and with admirable results. At present the extensive mining operations in this locality are carried on entirely by the Chinese, the country being an "El Dorado" of mineral wealth.

N.

Franklin Institute.

HALL OF THE INSTITUTE, May 19th, 1880.

The stated meeting was called to order at 8 o'clock P. M., the President, Mr. William P. Tatham, in the chair.

There were present 135 members and 29 visitors.

The minutes of the last meeting were read and approved.

The Actuary presented the minutes of the Board of Managers, and reported that 12 persons were elected members of the Institute at their last meeting. He also announced the award of the Elliott Cresson gold medal to William Farr Goodwin, for his mowing machine, in accordance with the recommendation of the Committee on Science and the Arts.

The Secretary reported the following donations to the Library:

Letter from Secretary of War transmitting Papers of Second Installment to Jas. B. Eads. From the War Department.

Catalogue of Pennsylvania State College of Agriculture. 1879—1880. From Jas. Calder, President.

Circulars of Information of the Bureau of Education. No. 1, 1880. From the Bureau.

Letter of the Commissioner of Agriculture to Hon. J. W. Johnston on Sorgham Sugar. From Agricultural Department.

Annual Report of Friends' Free Library of Germantown. From the Library.

Papers read before the Pi Eta Scientific Society. 1879—1880. From the Society.

Charter and By-Laws of the Pennsylvania Museum and School of Industrial Art. From the Museum.

Measurement of Powder Pressures in Cannon. From Charles Bullock.

Tenth Annual Report of Lake Shore & Michigan Southern R. W. Company. From the Company.

General Systems of Measurement for Urethal, etc., and Researches on Hearing, by C. H. Thomas, M. D. From the Author.

Special Report of New York State Survey on Niagara Falls. From Jas. T. Gardner, Director.

Transactions of the Wisconsin State Agricultural Society. 1873—1879. From George E. Bryant, Secretary.

Twenty-first to Twenty-third Annual Reports of the Secretary of the Board of Agriculture of Maine. From L. S. Ware.

Iron and Steel Works of United States. 1880. From American Iron and Steel Association.

Crosby Steam Engine Indicator. From G. H. Crosby.

Twenty-sixth to Twenty-eighth Annual Reports of the Indiana State Board of Agriculture. From the Board.

Eighth to Tenth Annual Reports of the Geological Survey of Indiana, 1876—1878, by E. T. Coxe. From the Author.

Annual Reports of the Operations of the U. S. Life Saving Service for the year 1879. From the Treasury Department.

Report of the Council of Education upon the Condition of the Public Schools of N. S. W. 1878. From W. Wilkins, Secretary.

Council Books of the Corporation of the Cities of Cork and Kinsale, by R. Caulfield. From the Author.

Annales Industrielle. 1869—1874. Text and Plates.
From L. S. Ware.

Mr. W. Barnet Le Van read a paper on "High Railway Speeds," suggested by the trial trip of the locomotive built at the Baldwin Locomotive Works for the Reading Railroad Company, and intended to run from Philadelphia to New York in 90 minutes, or at the rate of a mile a minute. To do this it must be capable of running at a faster rate on parts of the road to make up for time lost in passing over bridges and through towns, where a slower rate is necessary. To accomplish this with safety the road bed must be in perfect condition, and some changes must be made in the form of locomotives as now commonly used. This new locomotive has a single pair of driving wheels $6\frac{1}{2}$ feet in diameter, in place of coupled drivers of $5\frac{1}{2}$ feet in diameter. In the latter form of engines run at high speed there is danger that the coupling rods connecting the driving wheels will be broken by centrifugal force. The larger wheel also reduces the number of revolutions per mile of run. In the new locomotive the boiler has 1400 square feet of heating surface and about 56 square feet of grate surface. The dimensions are as follows: Diameter of cylinder, 18 inches; length of stroke, 24 inches; diameter of driving wheel, 78 inches; wheel base, 21 feet 1 inch; distance from centre of driving wheel to centre of trailing wheel, 8 feet. The boiler is made of $\frac{7}{16}$ inch steel and is 52 inches in diameter. It contains 198 tubes 2 inches in diameter and 12 feet $2\frac{3}{4}$ inches long. The fire box is $96\frac{1}{2}$ by 84 inches. The capacity of the tender is about 3,800 gallons of water, and weight when filled with water and coal, 70,000 pounds. The weight of the engine is 85,000, and is so disposed that by an alteration of fulcrum points additional weight can be thrown on the drivers at the time of starting. At a trial trip on May 14th, the engine was attached to a train of four cars, each weighing about 42,000 pounds, making the weight of the train complete, about 148 tons. The run was made at rates ranging from 27 miles an hour, between Ninth and Green and Wayne station, to 63 miles an hour, between Trenton Junction and Bound Brook, the time from Ninth and Green to Jersey City (89.4 miles) being 98 minutes, or at the rate of $54\frac{3}{4}$ miles per hour. On the return trip the run was made in 100 minutes. In a former trip the engine developed a speed of nearly seventy-nine miles an hour. In these trial trips the engine consumed 36 gallons or 300 pounds of water per minute. Mr. Le Van prophesied that within five

years "passengers would be set down in New York in one hour's time from this city." The average time on English railways is 46 miles per hour, on French 37½, on German 40, and on American 37. On English railways, 6½ feet driving wheels are quite as common as 5½ wheels, and some of the fast lines have 8 and 9 feet wheels, one line having 10 feet wheels. Engines with one pair of drivers are not new in this country, and Mr. Le Van described several which had been built at the Baldwin Locomotive Works, by Eward S. Norris and Norris Brothers, and by Ross Winans, of Baltimore. Some of these developed high rates of speed.

At the conclusion of the reading of the paper Mr. J. Snowden Bell said he regretted that Mr. Le Van had not informed the Institute about the grade of the road and the steam pressure during the trial trip. In considering the capacity of engines it is very important to know the grades of the road and the capacity of the engine for generating steam. He spoke of a trip he had made over the line last Monday in a regular train, when the odor of gas from the engine was very strong, and the engine ran with noticeable irregularity.

Mr. Le Van said that the grade, he believed, was about 56 inches to the mile. On the trial trip the steam pressure was 140 pounds at the start; it ran down to 90, owing to the use for a time of poor fuel, and when the train reached Jersey City it was about 130. On the return trip the engine started with pressure at about 140 and reached Philadelphia with about 120 pounds. He had no doubt that a pressure of 120 pounds would be required for a steady run. He said that he believed this new engine had all the elements of speed.

Prof. Marks said that he had made some calculations of the maximum speed at which engines could be driven before the centrifugal force on the tires of driving wheels would become so great as to cause them to burst. These calculations, which were approximate only, showed that the limit of speed was in the neighborhood of 150 miles an hour, and we have already attained 78 miles an hour, or more than half that limit. He was asked whether there was not danger that the heating effects of such rapid travel would be so great as to destroy the axles and bearings. He replied that Dr. Lardner had published what he considered demonstrations that the heating effects of revolving paddle wheels of steamships would be so great as to burn them up before they could get out of their docks, and in view of the practical refutation given to those "demonstrations" he did not think it worth

while to make similar prophecies about the heating effects of high rates of speed on railways.

In reply to an inquiry from the President as to the authority for the statement about Dr. Lardner, Prof. Marks said that an American edition of Lardner's lectures had been published in New York, he thought, in 1832.

A gentleman inquired whether, in view of the increased speed of trains, the trestle work bridges on the Bound Brook route were to be strengthened, saying that, while crossing one of the long bridges recently, the passengers in a train were startled by the vibrating of the bridge.

Mr. Le Van said that, on the trial trip, the day being calm, he had gone out on the platform to notice the effect in crossing the bridges, and there was no unusual vibration or swaying of the structure. He understood, however, that the bridges were to be strengthened and made entirely safe for the running of fast trains.

Mr. R. R. Atchison, of New York, presented samples of work done by his new metal, wood and stone working machinery, and presented a paper descriptive of the uses to which it could be applied. He claimed for the machine a new mechanical movement, the bits (in pairs) with which the work is done having a continuous rotary motion, as well as an alternating percussive stroke. This, he says, gives a new and peculiar cutting action with not only the fast clipping power of the pick or chisel when used by hand with a twisting motion, but the smooth, steady work of a rotary bit. The resistance to feed is much less than with a routing tool, which is always in contact with the work. In the new machines the bits are out of the work more than they are in it. The inventor claims that the wear on tools is considerably less than one-half compared with hand work, and that they can be used constantly on granite for at least one hour without changing. One set will cut not less than 360,000 blows, without requiring to be resharpened—equal to five hours of hand work. A large machine for stone cutting, now in use in New York, dresses blocks of granite eight by five feet on the ground and 3½ feet high, and can be adapted to work larger blocks. The head is given all the various feed motions required for different kinds of work, but, unlike an ordinary pit planer, the head cuts on the return as well as on the out-stroke. The wood-working machines have the same peculiar mechanical movement. They are particularly adapted to carving advertising signs, making pattern

blocks for printing, wood blocks for circus and theatrical printing, etc. The metal-working machine is similar to the others, but much smaller, and is already in use for matting and chasing jewelry and silver ware. Several beautiful specimens of the work of the machine were exhibited.

Mr. J. E. Mitchell said he was happy to hear that there was at last a machine that would economically dress such a hard stone as granite, but he desired further information on that point, and inquired what amount of granite could be dressed in an hour.

Mr. Atchison replied that the machine would cut granite at the rate of 9 square feet in 12 minutes $\frac{1}{16}$ of an inch deep.

Mr. Mitchell said that that was not deep enough to dress off a block as it comes from the quarry.

Mr. Atchison said that the operation could be repeated as often as required, and that, if there were great irregularities, the cutters could be employed only in the higher parts, until they were gradually reduced to the general level.

After further inquiries Mr. Mitchell figured out that to remove one inch from 9 square feet of granite would require three hours, and he thought this was not enough to make the machine economical. He then inquired about the tools, and being told that they struck 6000 blows per minute, and could be run for an hour without sharpening, said that they must be made of steel of remarkably fine quality.

Mr. Atchison said that they would not be dulled as quickly while striking 6000 blows per minute as if they were run at slower speed, say 4000 blows per minute.

Mr. Mitchell inquired as to the cost of the machine.

Mr. Atchison said that only one large stone cutting machine had been built, that now in New York. It was the first of its kind, and had cost $3000, but every one who had ever undertaken to build a first machine would understand that duplicates could be made for much less. This machine had been run experimentally for about a year, and on its performances were based the statements he had made as to its capacity.

Specimens of aluminium obtained by a new process, and of its alloys, were exhibited by the Pennsylvania Nickel Works. A paper on the subject stated that, in 1827, Prof. F. Woehler discovered the metallic base of clay—aluminium—and that it was not until 1854 that Henry St. Clair Deville, after many experiments, succeeded at last in gaining the metal in larger quantities, and in introducing it in the metallurgic

industries. He reduced chloride of aluminium by heating it with sodium in dry hydrogen gas, and up to the present time his laboratory has been the only source of supply. In 1858, Mr. William Frischmuth, of this city, employing a similar process, gained aluminium, but his labors were financially unproductive, and he abandoned them to raise a regiment during the war. Quite recently, while experimenting with nickel ores, he discovered a more direct method of smelting aluminium, and he exhibited ingots produced by his process. He said that the metal could be obtained cheaply and almost chemically pure, so that it can be extensively used for the manufacture of articles requiring a strong, light metal, such as mathematical, optical and surgical instruments. The color of the metal is white, it polishes like silver, does not tarnish, has the tension of copper, and a specific gravity of 2·65, that is to say, it is four times lighter than silver. Its alloys promise to be particularly useful. With nickel it forms a tractable compound called Alu-ni, which was patented last December to be used for electro-plating. Alloys of aluminium with copper and with iron also promise to be useful in manufactures and for electrical conducting wires. The metal itself is very ductile, and can be drawn into the finest wire. It takes the place of silver in bronzes, because of its lightness and untarnishing qualities. The pure metal and its alloys are manufactured at the Pennsylvania Nickel Works of Frischmuth & Van Tronk.

Prof. Marks exhibited a Peaucellier compound compass, a beautiful piece of workmanship made by Mr. Young, of Philadelphia, and mentioned at the previous meeting as the only machine capable of drawing a straight line. He explained its construction, and said that he desired to convince Mr. Nystrom of the truth of his previous assertion, and to correct his statements as to the Sellers planer being capable of making a straighter line. The machine was afterwards shown at work, and, in the language of Prof. Marks, made a line "straighter than a straight edge." It was not designed, however, for this purpose, but to describe arcs of a radius from a few inches to infinity, and, being so compact, was of great use to draughtsmen and others, and capable of taking the place of immense beam compasses, requiring two men to operate them.

Mr. Nystrom examined the machine critically, and said that he had no doubt it would draw a straight line *if* certain rods or arms were made, according to the design, exactly of the same length; *if* certain

other arms were in a fixed proportion to these and exactly equal to each other; *if* the pins on which they worked were exactly true, and *if* they were perfectly fitted; there were not, however, so many ifs in the Sellers Planer, and he maintained his former opinion.

Among the novelties shown were the following:

Mr. Spellier exhibited a new pendulum suspension device, designed to keep the oscillations of the pendulum in a true plane only. This is secured by giving the suspending spring an even tension.

Griscom & Co.'s machine for re-fitting valves, a small hand lathe, with attachments to produce true bevels, could be used to repair valves on pipes or boilers without disconnecting.

Morse's adjustable shelving, a cheap device for supporting shelves and allowing the brackets to be adjusted to any desired height. The brackets fit into a toothed rack, which, being securely fastened vertically, the brackets themselves have simply to be put in place to prepare supports for shelves in stores, kitchens, conservatories, museums, or in any place where it may be desirable to have adjustable shelving.

Rutherford's adjustable horse collar and hames, made of malleable iron and capable of adjustment to fit any horse and to allow a change of draft to suit the work.

A model of A. B. Turner's patent underground telegraph line. The design is to form sections of glass, furnace slag, or other insulated material, to be laid like sections of terra cotta drain pipe, but having, instead of one hole, a number of small holes, each to contain a single uncovered wire; also to have relays, etc., to allow tests of the line and the turning of corners.

Batchelder's Patent Scintillating Gas Lighter, giving 4000 lights with one charging of the apparatus; Crawley & Develin's Shutter Locking and Bowing Fixture; Rogers' Sewing Machine Scissors, with screw-driver, wrench, etc., combined; Peterson's Patent Waterproofing Material, and Howard's Metallic Brushes.

A letter was read from Prof. Henry Morton by the Secretary, stating that, in the examination of the Brush Co.'s Electric Lights at the Coney Island Pier, they were not in charge of the Company, and the results as read at the March meeting* were probably anything but an average performance.

* See JOURNAL, pp. 284 and 418.

An abstract was also read from a paper concerning the early use of anthracite coal in Pennsylvania.

Prof. Frazer's resolutions with regard to an appointment of a committee of chemists to report on the scientific value of some expert testimony given in a recent trial, came up as deferred business from the last meeting, and was, on motion of Mr. Chabot, again postponed.

Mr. J. W. Nystrom offered the following:

In the May number of the JOURNAL I am recorded to have said that "When a governor, running at a constant speed, can keep it almost closed, it is practically an isochronous governor." It should have been reported: "When a governor, running with a certain constant speed, can keep the throttle-valve of a steam engine wide open, and can also keep the same throttle-valve nearly closed whilst running with the same constant speed, then the governor answers the purpose of isochronous, and is therefore practically so."

I also said that cycloidal pendulums were tried on clocks in Vienna, but not "some years ago," as the minutes make me say. The isochronal properties of the cycloid was discovered by Galileo in the year 1615, and applied to clock pendulums by Huyghens about the year 1655, or 225 years ago. The principle of applying the cycloidal pendulum to clocks is described and illustrated in works on clockmaking, published in the principal languages of Europe in the last century.

The minutes also make me say that the term "isochronous can really be of no practical use," although I expressed my desire to "retain that term for practical use," as there is no other term in the English language which expresses that property of a governor.

The subject was discussed by Messrs. McKean, Eldredge, Burk and others, and on motion the corrections were ordered to be referred to the Committee on Publication, that they might appear in the JOURNAL.

Mr. Hector Orr offered the following resolution:

Resolved, That by the death of MR. JOHN MCCLURE our community has lost a valuable citizen and our Institute a model member. That we recall with gratification his long services among us, and while we here record our sincere regret at the deprivation now incurred, we commend his example to all survivors and successors.

On motion, the Institute adjourned.

ISAAC NORRIS, M. D., *Secretary.*

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